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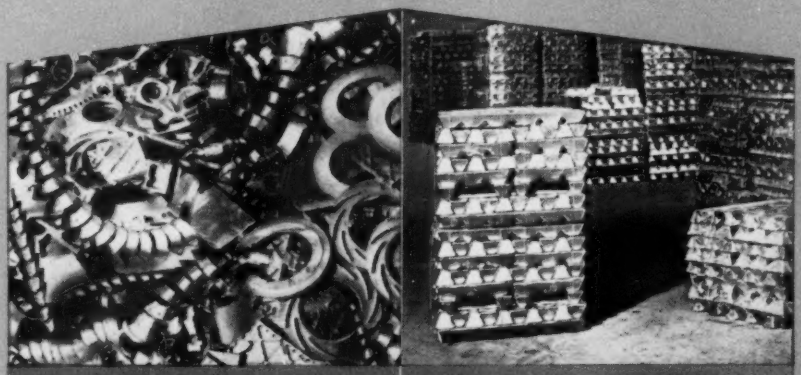

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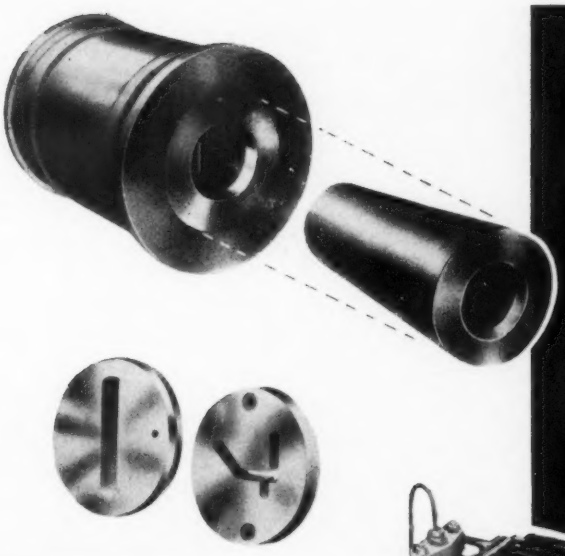

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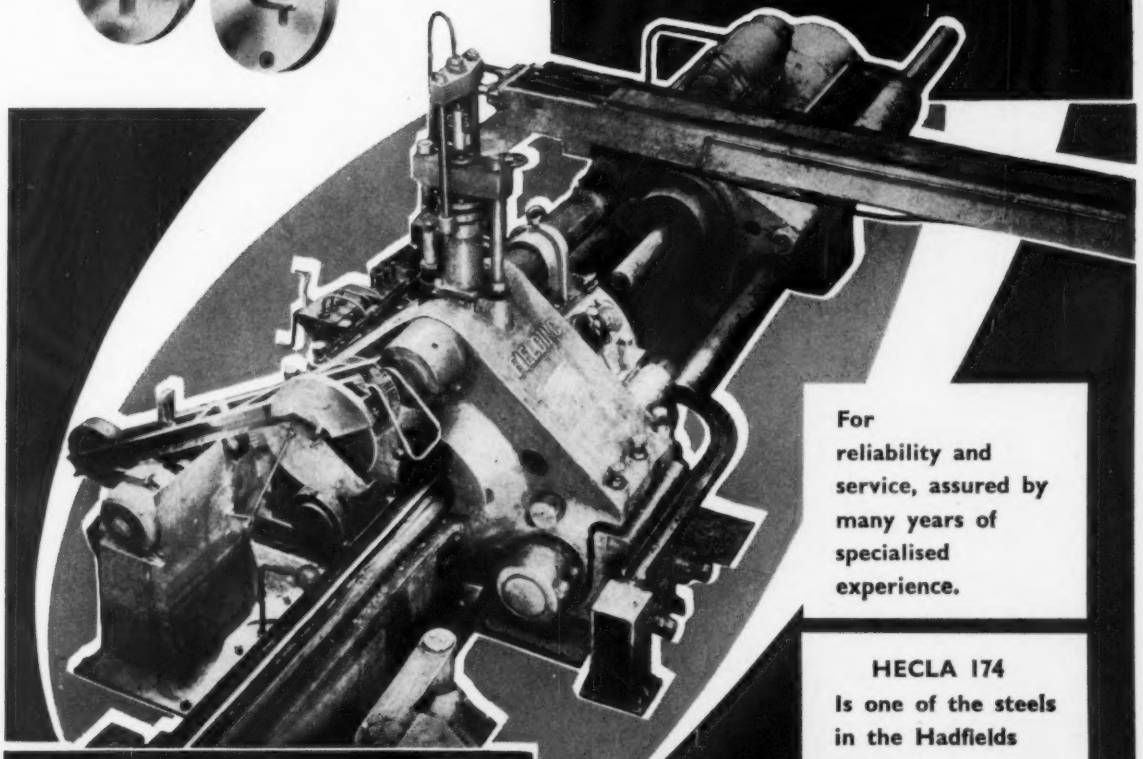

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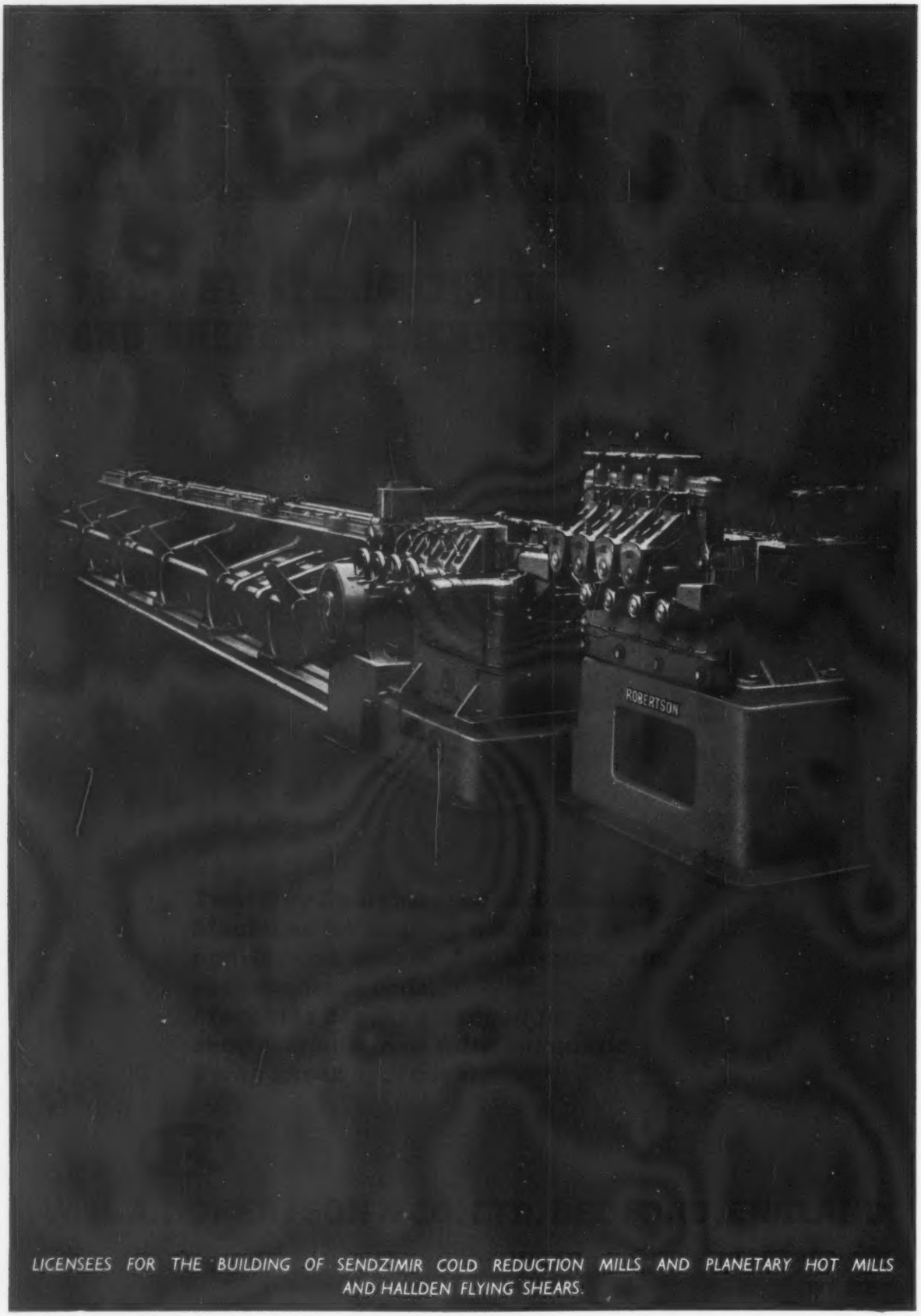

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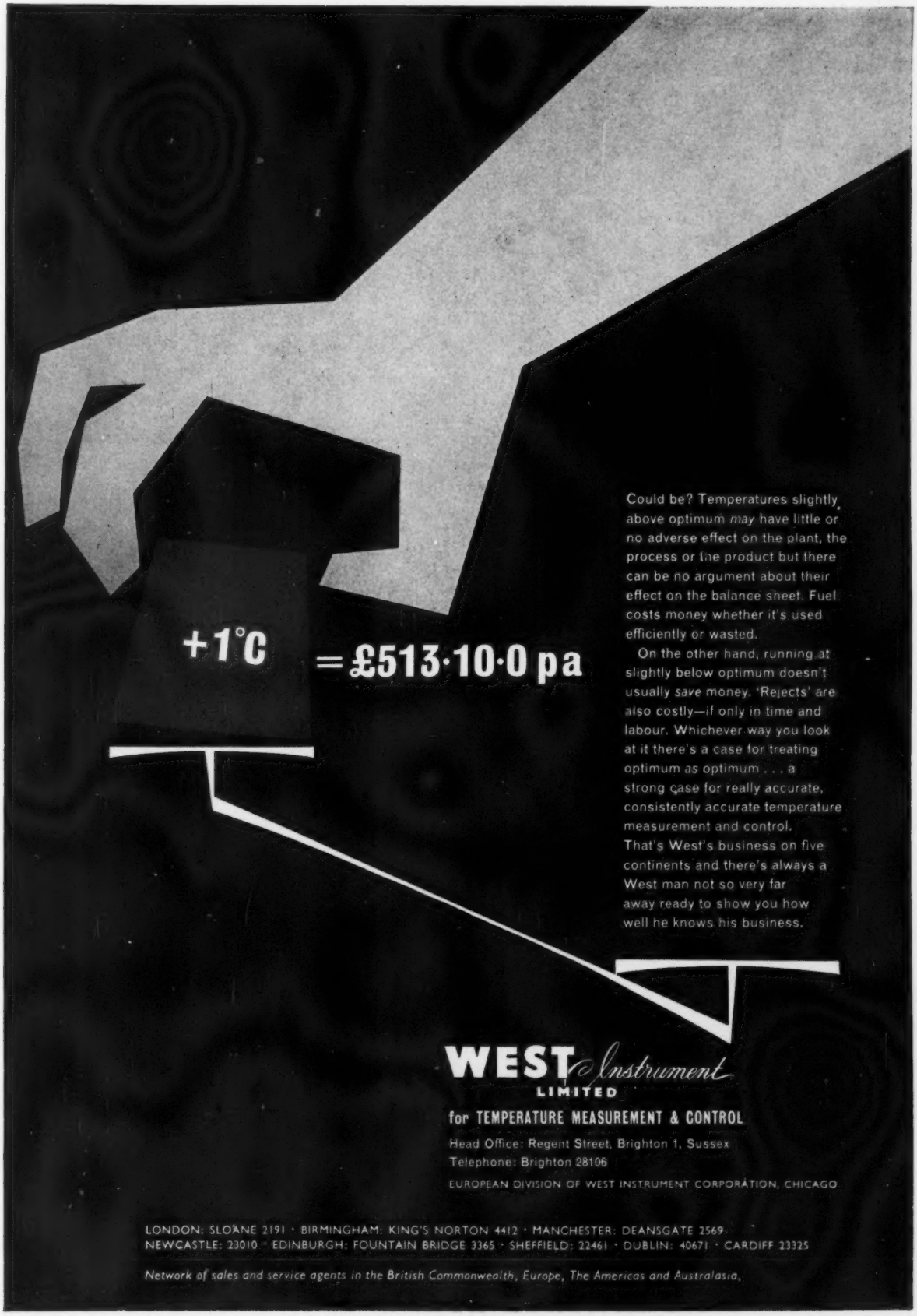
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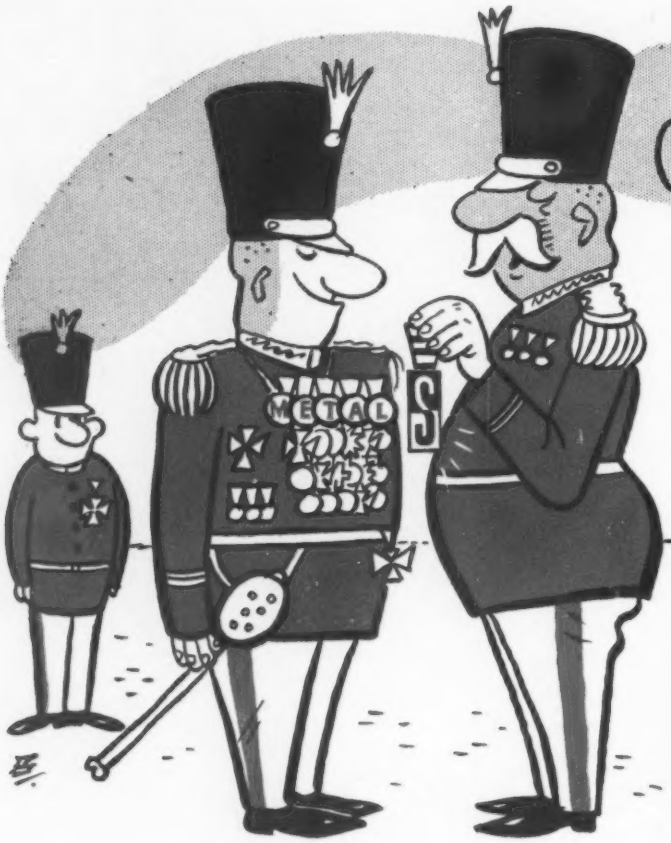

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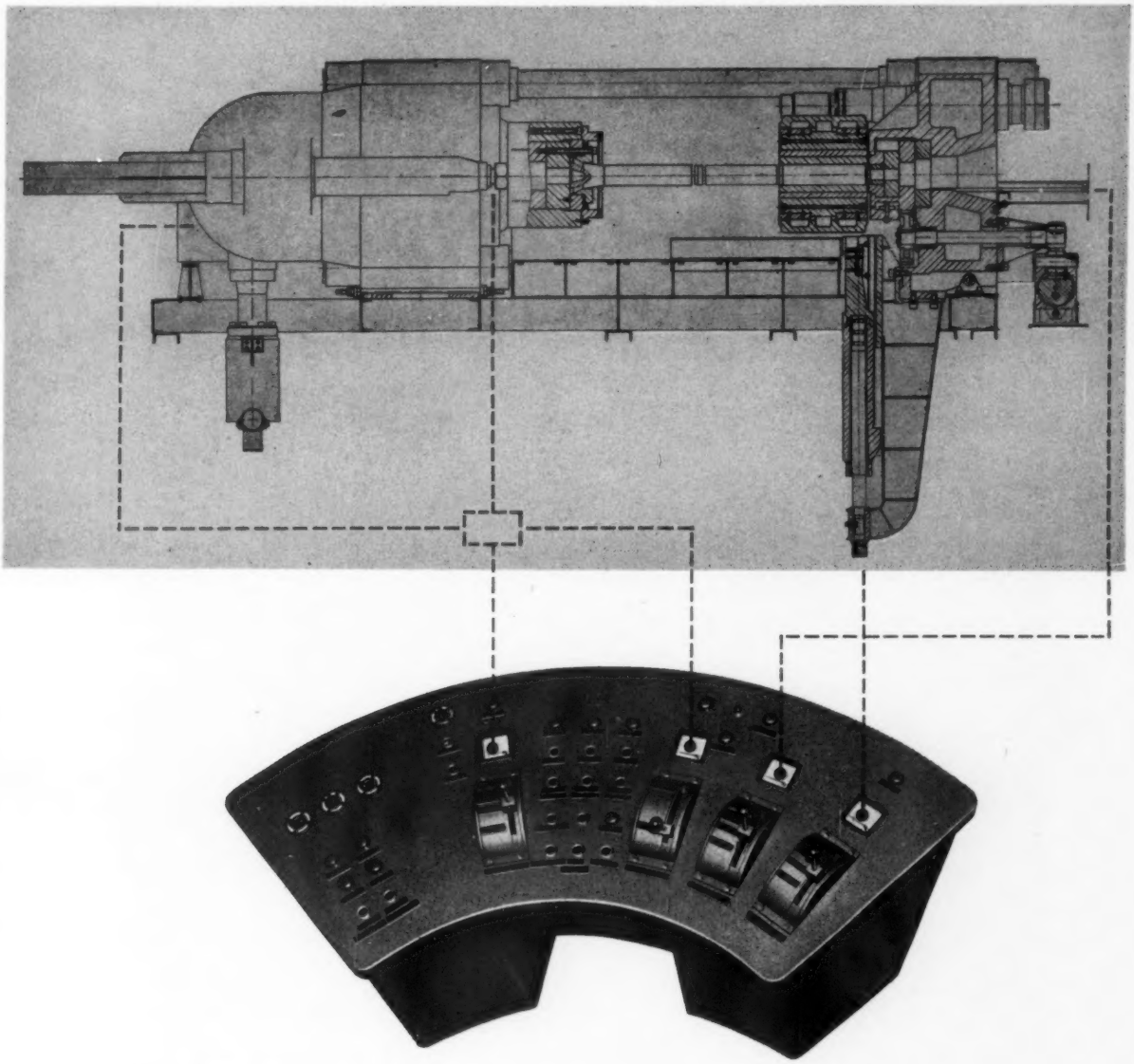

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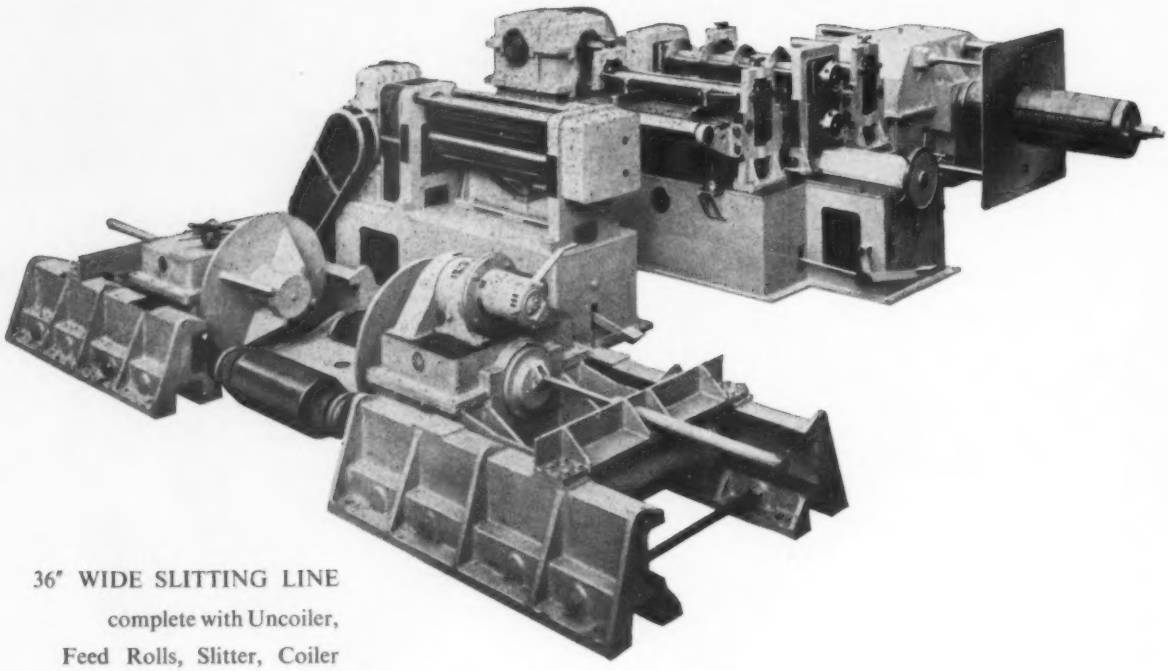

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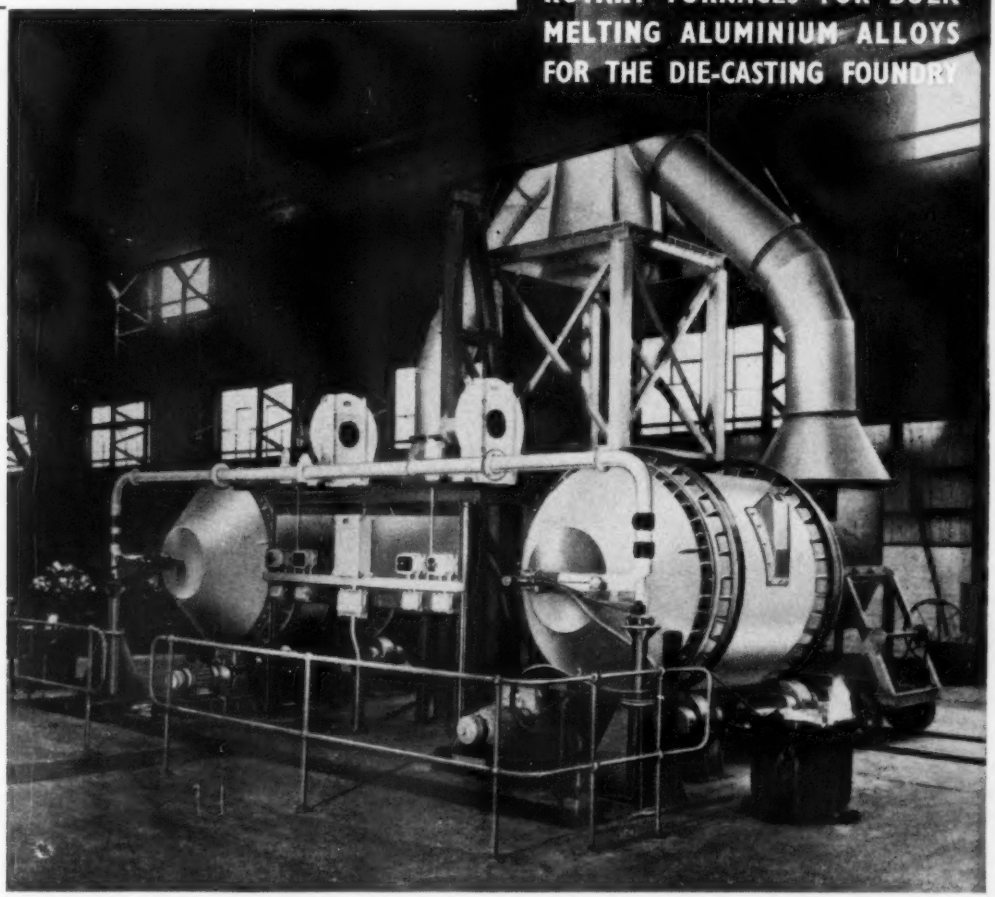

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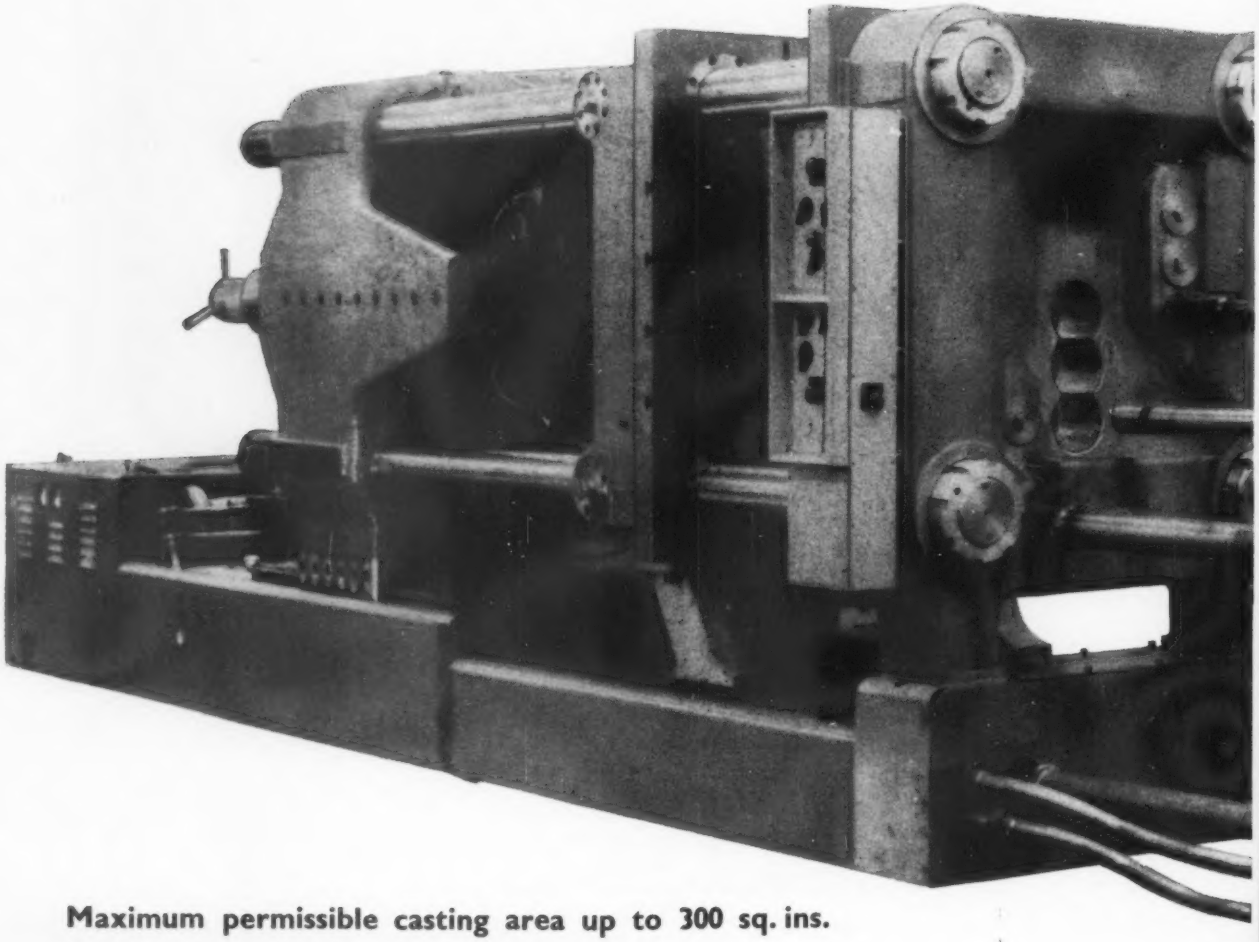

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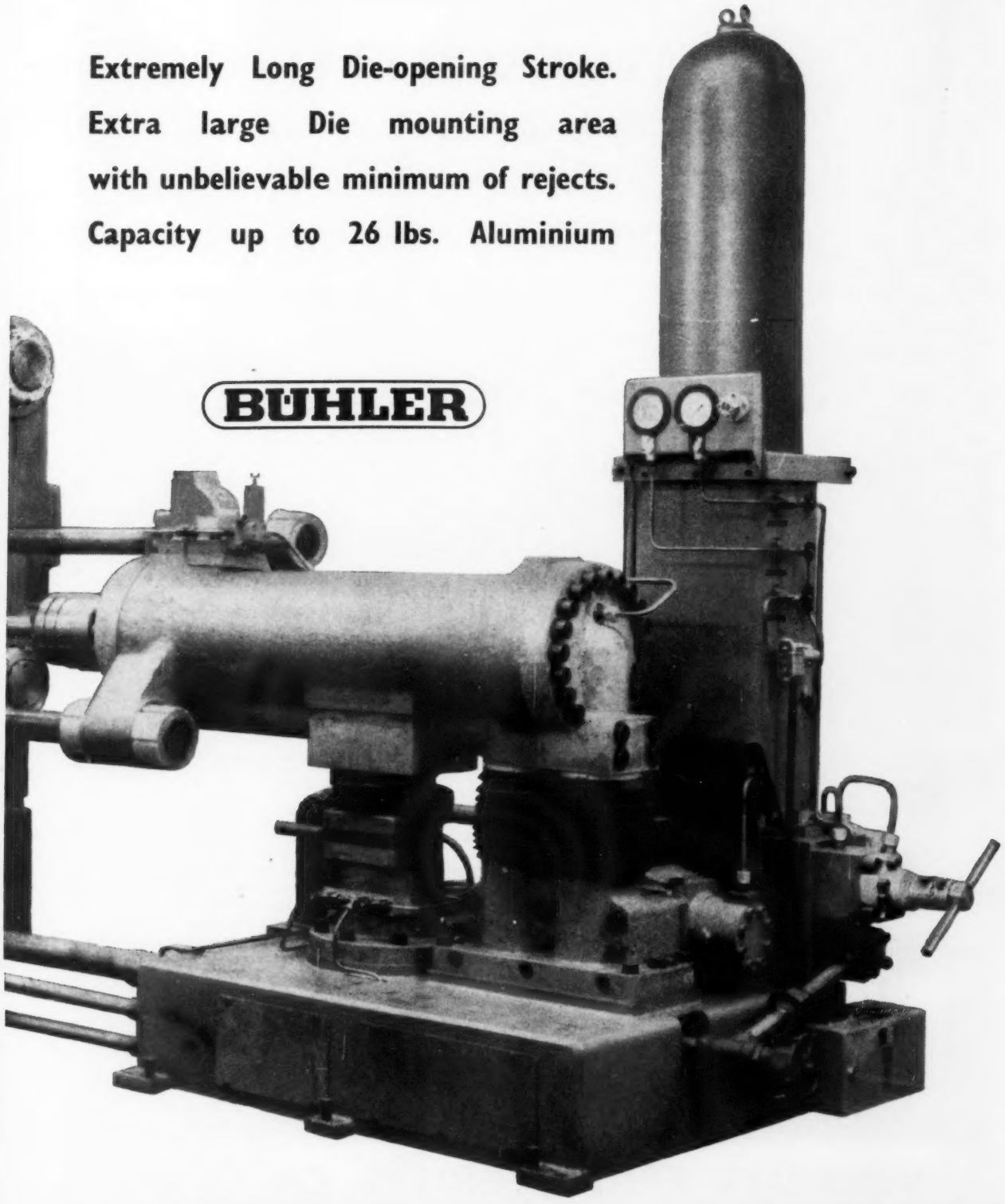

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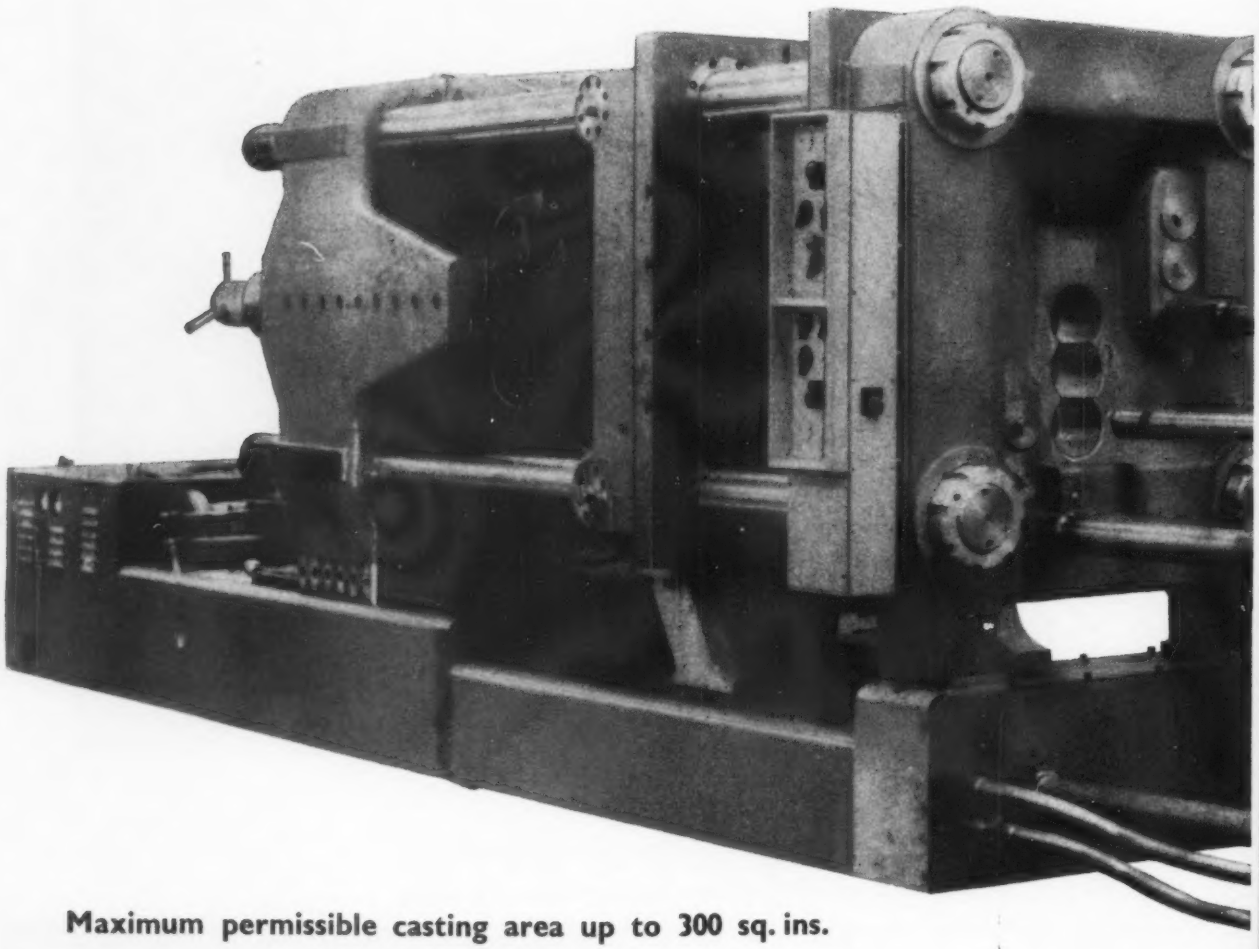

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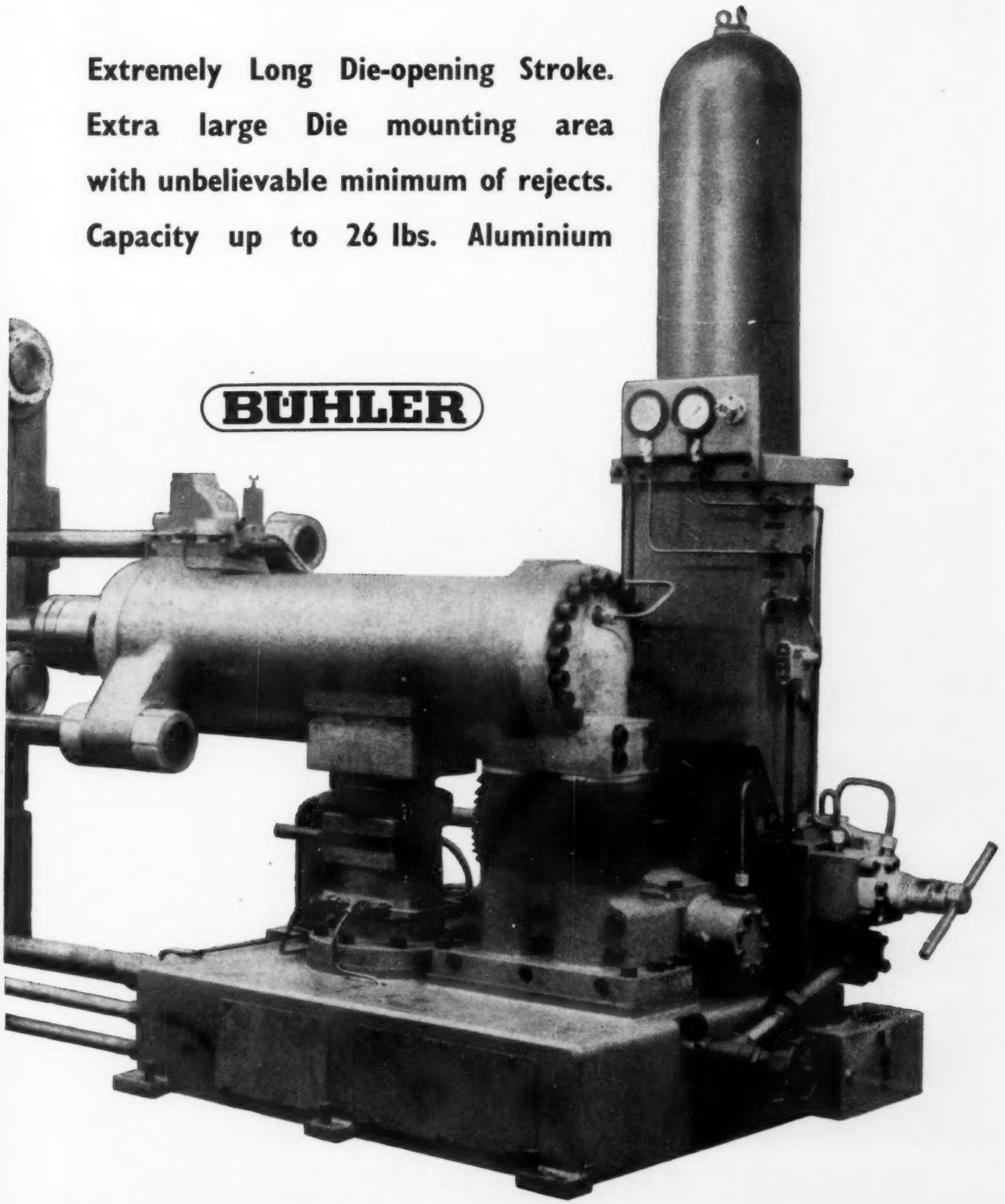

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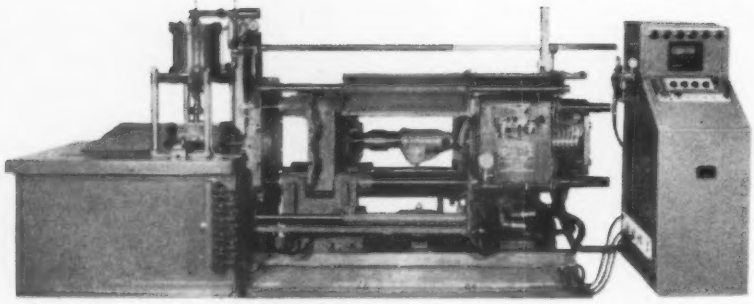

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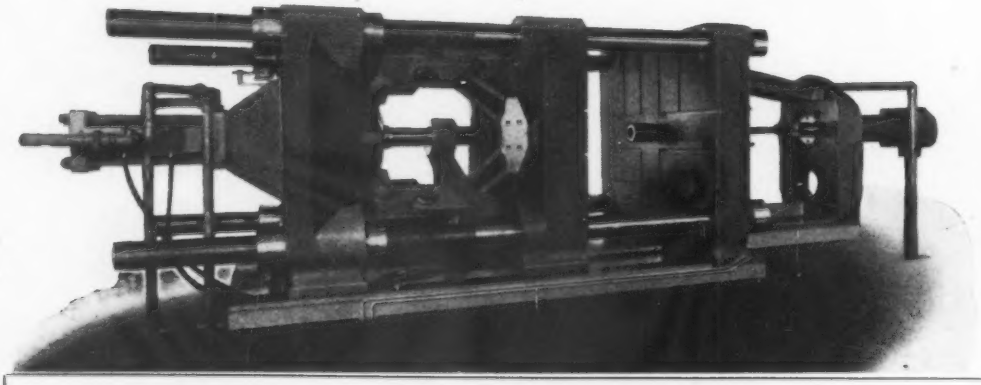

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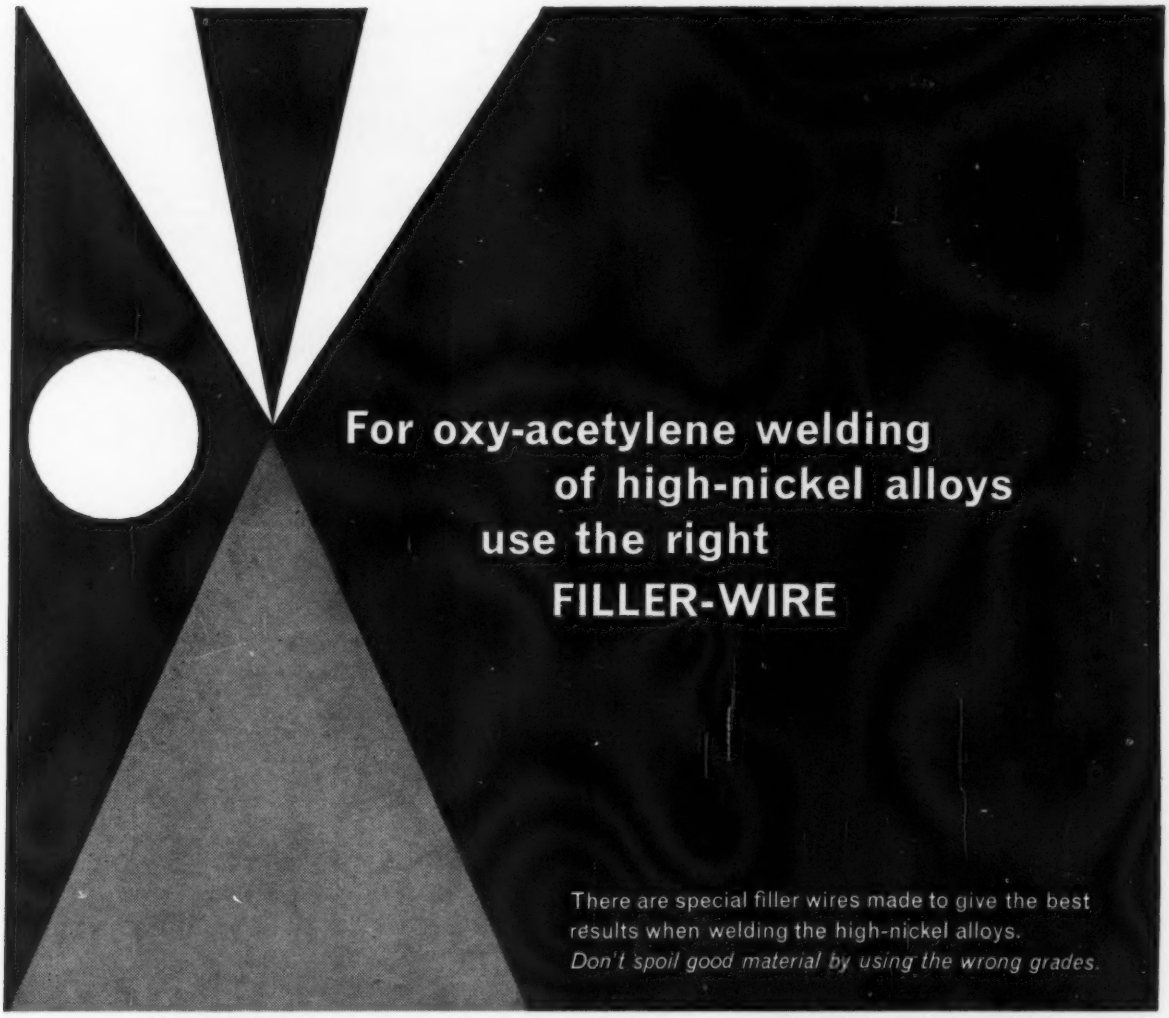
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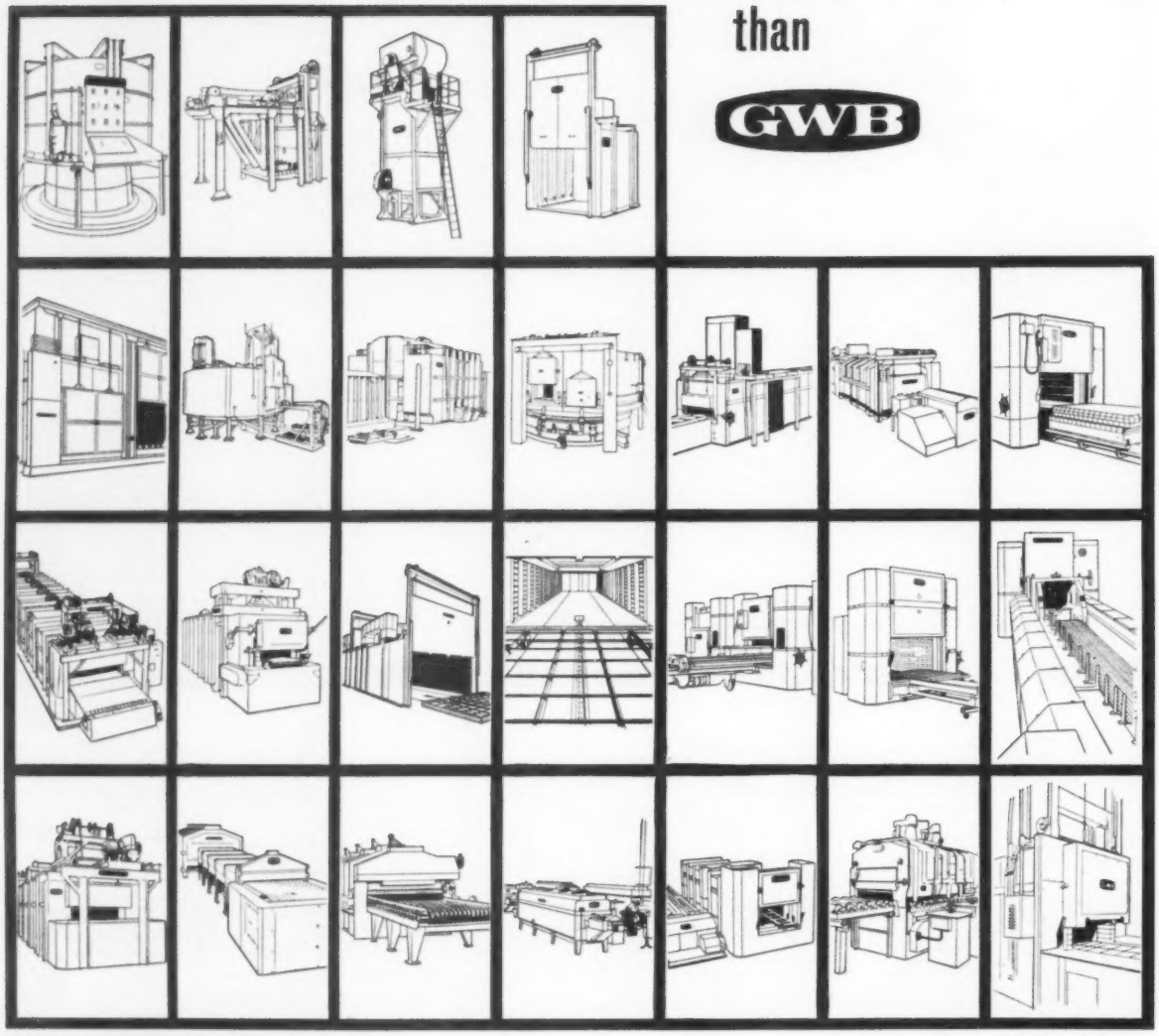

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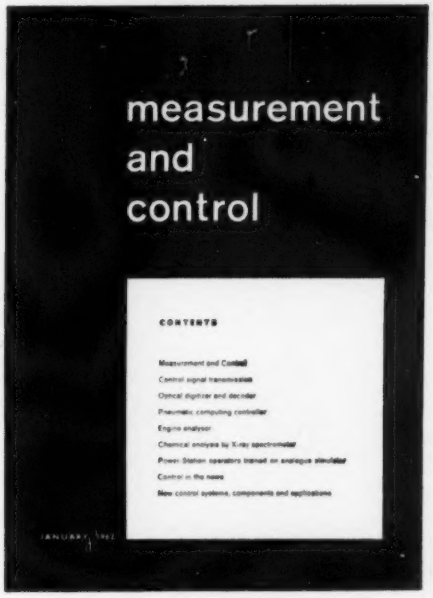

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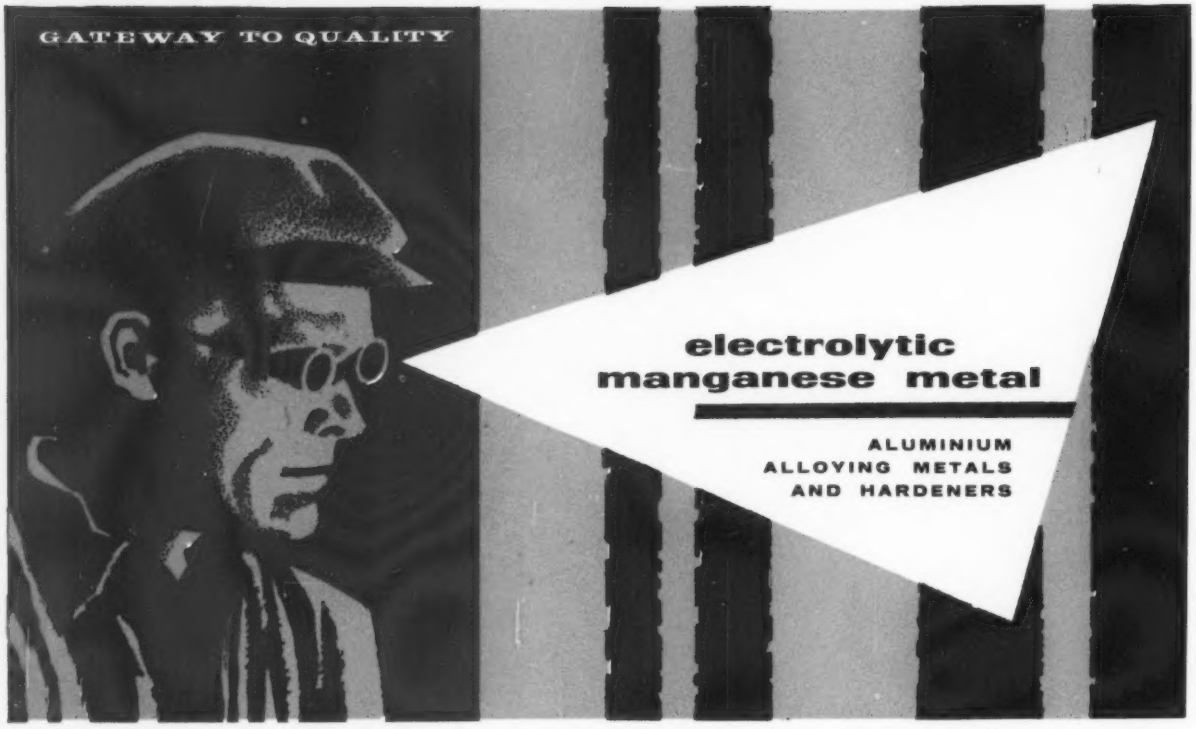

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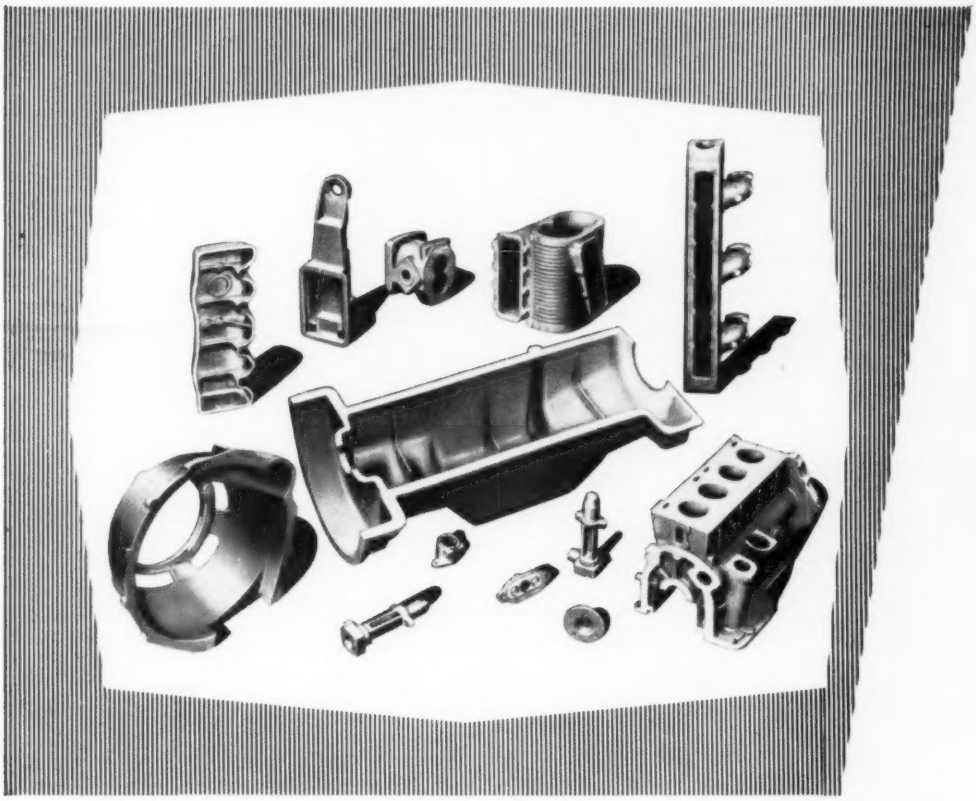

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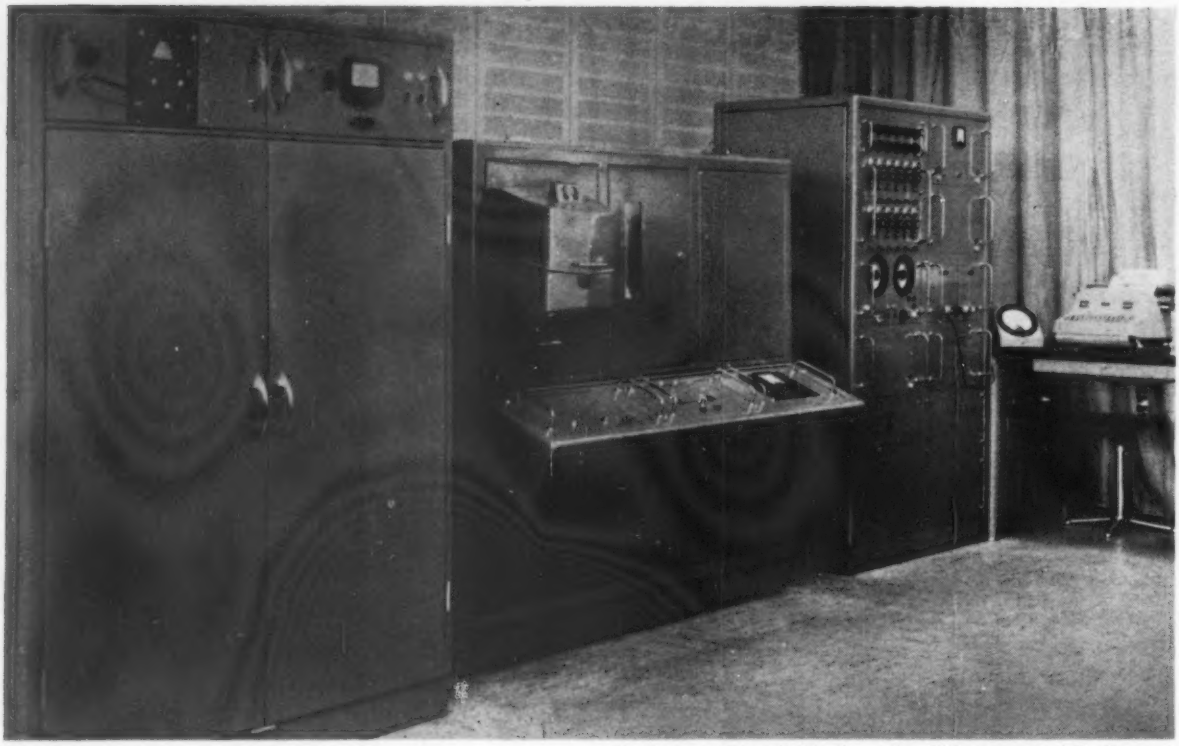

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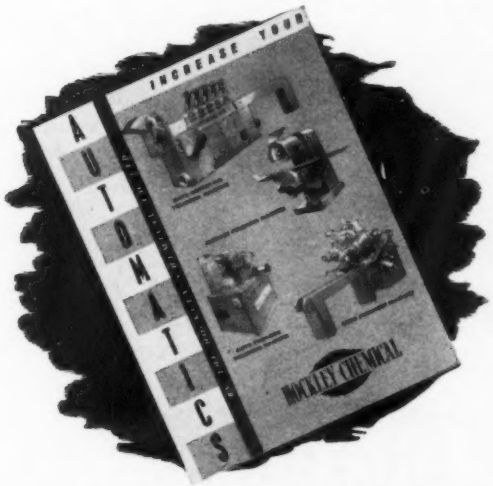

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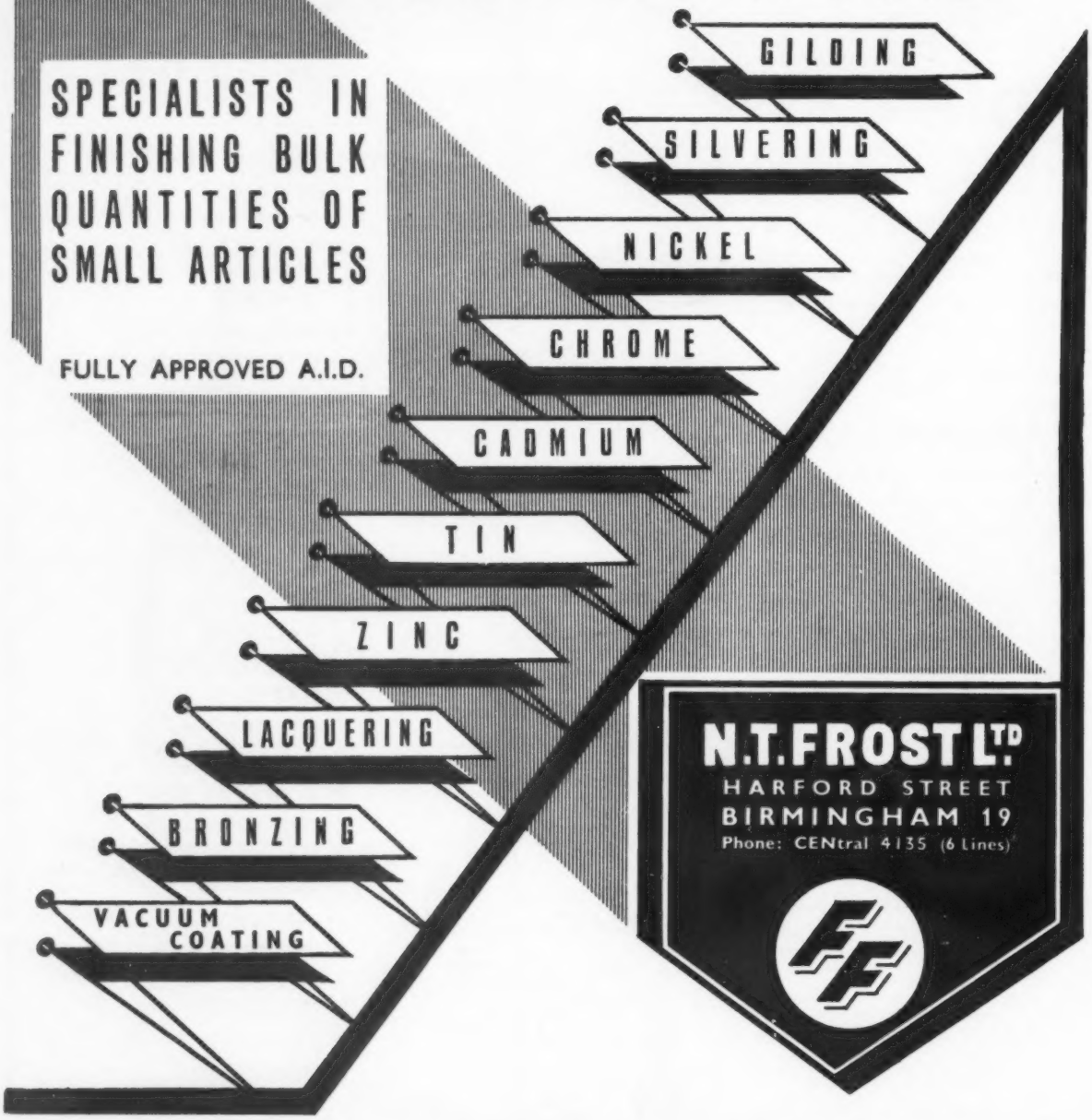

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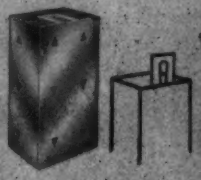

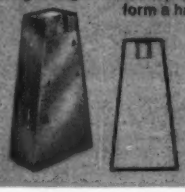

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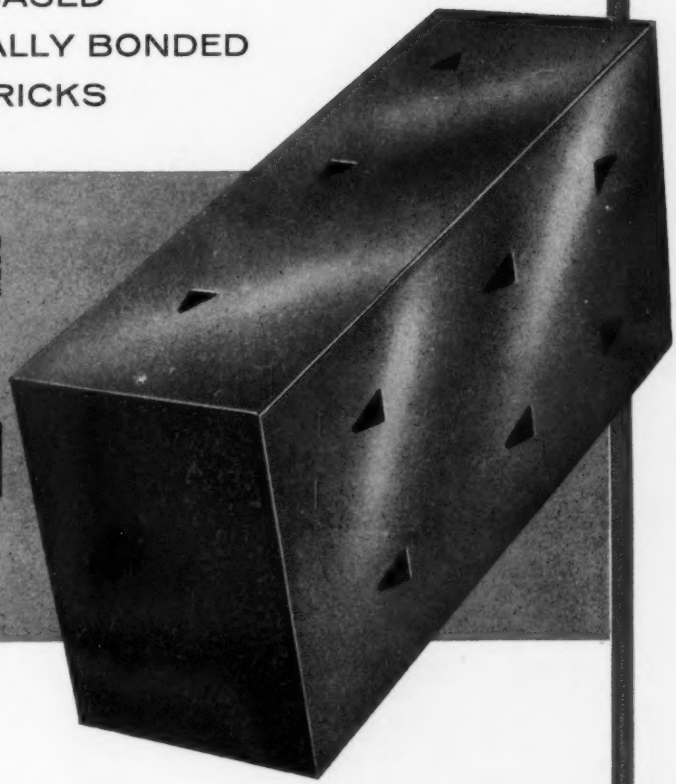

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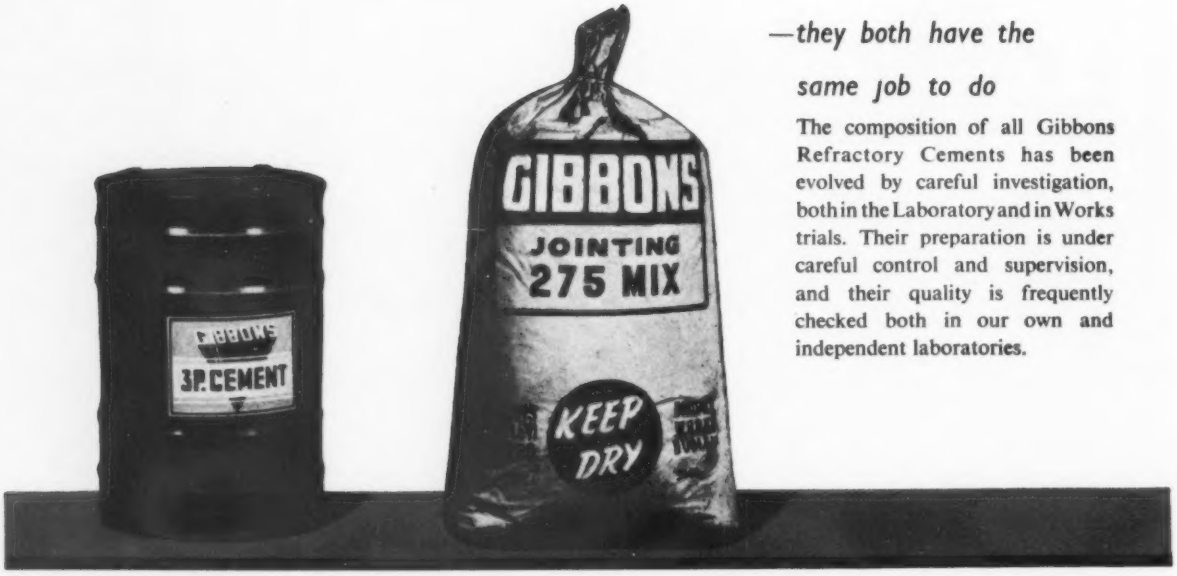

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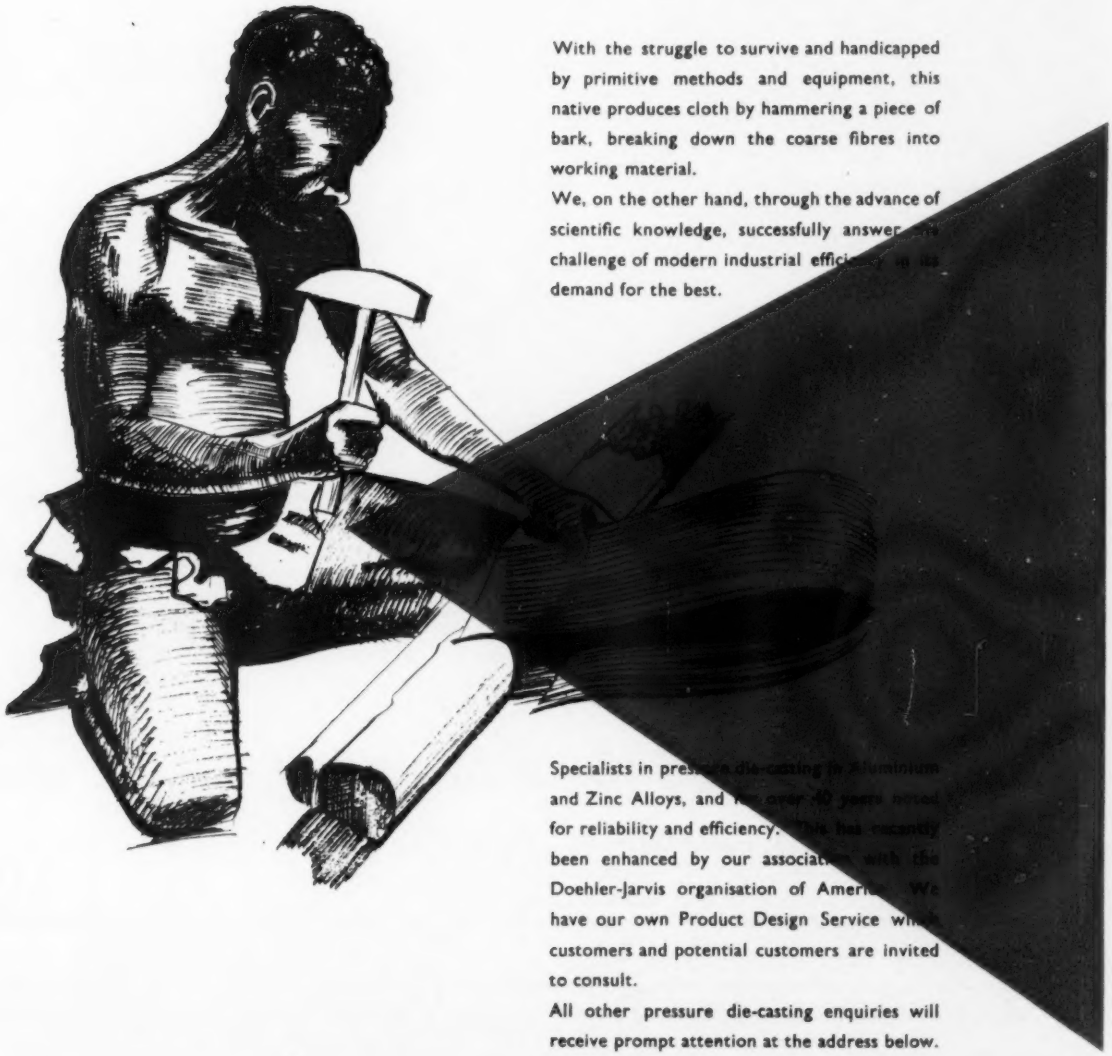

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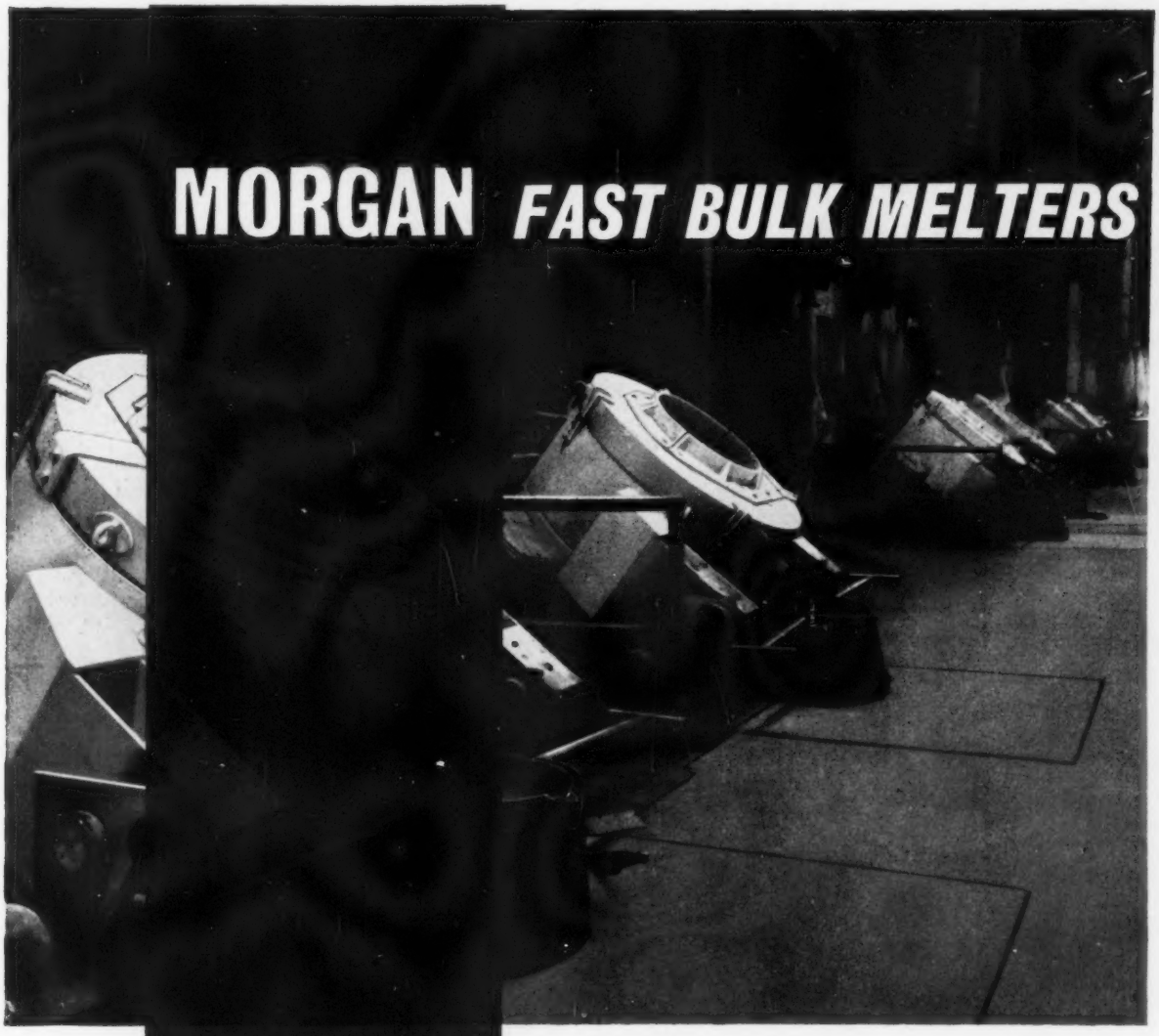

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METAL INDUSTRY

FOUNDED 1909

6 October 1961 Volume 99 Number 14

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L. G. BERESFORD, B.SC., F.I.M.

MANAGING DIRECTOR
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METAL INDUSTRY

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VOLUME 99

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Autumn Meeting

ALTHOUGH the numbers taking part in the Autumn Meeting of the Institute of Metals in Belgium were not as large as usual, the meeting was entirely successful. Discussions at the technical sessions were lively and stimulating, the social functions were well organized, and the works visits varied and interesting.

The question is sometimes asked as to whether in these days these foreign meetings serve any useful purpose. Before the war, opportunities for inspecting works abroad were few and far between. Nowadays there is a constant flow of technicians between this country and the Continent—a two-way passage made possible because of the breakdown of that relic of pre-war days, the desire to keep one's plant and processes secret. (In this connection it must be said that the Institute of Metals itself has had much to do with this breaking down of prejudices.) It is also argued that the cost of attending these meetings is beyond the pockets of those who would benefit most by attending—the more junior technicians. Nevertheless, we feel that these meetings are still worth while. They enable people to mix at all levels, they engender friendliness, and, above all, they cement international relationships.

As was only to be expected, the Common Market loomed large in many private and some official discussions. The Autumn Lecturer, Baron Snoy et d'Oppeurs, to some extent set the pattern. As one of the principal negotiators of the Rome Treaty on the Common Market and Euratom, and a past chairman of Council of the Benelux Union, he is particularly well qualified to talk on the subject. His address was noteworthy for the facts and figures produced to show the advantages that have accrued to Belgium in particular by this economic co-operation. In view of the approaches now being made by Great Britain, his lecture was peculiarly appropriate and must have convinced many of those inclined to waver.

Similar conclusions are drawn by M. Marcel de Merre (President, l'Union des Industries de Métaux Non-Ferreux) in his article on page 270 of this issue. At present the countries of the Common Market absorb about 50 per cent of the products of the Belgian non-ferrous metals industry, but he foresees that an extension of the Common Market frontiers will create new opportunities for development and greater stability. The relations between the Six and the United Kingdom, with its commitments to the Commonwealth and the European Free Trade Association, certainly present problems of the greatest importance to the economic future of Europe and the West. Problems will also arise, particularly in the non-ferrous metal industry, if the present negotiations prove successful and Great Britain enters the Common Market, in regard to commercial policy and tariff controls, but, as M. de Merre comments, "industry itself has a primary role to play in the search for solutions to them".

OUT OF THE MELTING POT

Open

PARADOXICALLY, simplifying something or other does not always make things any easier; indeed it may introduce a number of uncertainties. Where, formerly, existing complications restricted the possibilities within certain fairly obvious limits and thus made them easier to survey, the elimination of some of these complications, and a corresponding widening of the limits, may make the possibilities correspondingly much more difficult to survey and subsequently to realize. Such thoughts arise in connection with the proposal to use an impact method of applying the load to spot welding electrodes. The reasoning behind this proposal is that spot welding machines could be lightened and made cheaper if the "press" requirements were removed and a moving weight used to deliver a blow to the "electrodes":—"a nail can be driven more easily with a light hammer than with a static press". The other advantage of doing away with press loading in spot welding is that the welder arms would also be eliminated, giving the possibility of making spot welds near the centre of large sheets or assemblies of complicated configuration which it would have been difficult or impossible to accommodate between normal or even expensive special welder arms. Together with the above advantages, impact spot welding also presents various uncertainties. There are the mechanical design problems of providing a falling weight or other means of delivering the required blow. So far as the welding process itself is concerned, there are the problems of the impact force and its relation to the welding current and time. Experimental impact spot welds have been made by turning on the power before impact, striking one of the electrodes, and then allowing current to continue for some time. The influence of the variables involved in these three stages of the process remains to be investigated.

Under Difficulties

NOW that the importance of fundamental research is generally acknowledged, conditions in which such research can be undertaken have all but ceased to exist. Like any other activity, if it is to be all that it can be in all possible respects, research, apart from the physical requirements, calls for an appropriate state of mind. In this connection, it is generally not appreciated that there is a fundamental difference between the states of mind required for the two types of research: there is a fundamental difference between being research-minded and being fundamental-research-minded, and so many present-day conditions combine to make the latter well-nigh impossible. There is, to begin with, the very success of fundamental research in the past, which now has the effect of almost ruling out the chances of any research that does not promise to do likewise ever being started. There is the growing sophistication that now rules out another characteristic constituent of fundamental research work, namely curiosity. The current responsible, adult, objective attitude to pure research is incompatible with the pure curiosity which in the past motivated so much research work and ensured its continuation regardless of expense, inconvenience and indeed unpleasantness accruing to those "foolish" enough to engage in such work. Today, research is no longer foolish, or, rather, "foolish" research is no longer undertaken. It can, of course, be argued that that is as it should be. This, however, then leaves us with the fact that the foolish kind of research is to be rejected as foolish, and it is at least arguable that this must leave us that much the poorer.

Tricks

IN spite of the respectable age of electroplating, remarks regarding the difficulty of learning new tricks in old age certainly do not apply. One really new trick that has recently been learnt is scribe-plating. On closer acquaintance with this process, the first idea suggested by its name: that it provides a means of localized plating, probably with the aid of a moving anode, is disproved. While the process is indeed one for localized—very much localized—plating, it has the novel feature that, in it, localization of the plating and the plating itself constitute two quite separate operations. As the name implies, the localization of the electrodeposition is effected by scribing. Using a fine stylus of a suitable material, a line is scribed on the surface to be scribe-plated. The process of scribe-plating is, in fact, based on the observation that the material in the region of the surface which is mechanically disturbed by the scribing exercises a preferential nucleating effect when the scribed surface is subsequently placed in a chemical or electrolytic plating bath, with the result that deposition of the metal from the bath can be confined to this disturbed scribed region. In this way, metals can be deposited on lines and other configurations that can be microscopically thin and small. Thus, lines having a thickness of the order of 1 micron have been successfully plated. Large numbers of such lines closely spaced together and running parallel or intersecting to form grids can similarly be plated. Scribe-plating appears very promising as a means of producing various miniature and microminiature electronic components (resistor and transistor elements) and systems. Indeed, so far most of the work on scribe-plating has, in fact, been performed with such possibilities uppermost in mind. Polished silicon and germanium slices have been scribed and the scribed lines and patterns have been plated with such metals as gold, indium, indium arsenide, gallium arsenide and chemical nickel. As a manufacturing technique for electronic elements, scribe-plating can usefully be supplemented by scribe etching: i.e. the preferential chemical etching of lines scribed on both germanium and silicon surfaces.

Skinner

Metal Industry, 6 *October* 1961

BELGIUM 1961

INSTITUTE OF METALS AUTUMN MEETING

[*Courtesy Belgium State Tourist Office*

FAVOURED with glorious weather, the 53rd Autumn Meeting of the Institute of Metals was held in Brussels from September 18-22, by invitation of the Union des Industries de Métaux Non-Ferreux.

Delegates were welcomed to the Conference by **Mon. M. de Merre,** President of the Union des Industries de Métaux Non-Ferreux, at the opening meeting at the Palais des Congrès on the morning of Monday, September 18. In a brief and charming speech, Mon. de Merre referred to the cordial relationship that had always existed between the metallurgists of Belgium and Great Britain, and expressed the hope that the delegates would find this meeting not only instructive but entertaining.

Thanking Mon. de Merre for his welcome, the President of the Institute of Metals, **Prof. Hugh O'Neill,** then introduced the Autumn Lecturer, **Baron Snoy et d'Oppuers,** who took as his subject "The Non-Ferrous Metals Industry in a Unified Europe". After tracing the history of the European non-ferrous metals industry between the wars, the lecturer dealt with the Common Market and its present and probable future effect upon the industry. He welcomed the approach that Great Britain is now making to join the Common Market, believing that a breaking down of trade barriers was the first step towards unification.

A vote of thanks to the lecturer, proposed by **Mr. G. L. Bailey,** was received with acclamation.

During the week three Technical Sessions were held, dealing respectively with "Deformation and Fracture", "Corrosion" and "Surface Friction and Lubrication in Metal Working". The proceedings at the first two of these will be published in this and subsequent issues of METAL INDUSTRY.

At the conclusion of the last technical session, a vote of thanks to the Belgian hosts and to all those who had contributed in any way to the success of the meeting, proposed by **Prof. Hugh Ford** and seconded by **Mr. A. B. Ashton,** was carried with enthusiasm.

In the unavoidable absence of Mon. de Merre, **Col. Berger-Hainaut,** chairman of the executive committee for the meeting, briefly replied.

The social aspect of the meeting was well catered for, starting with a cocktail party at the Metropole Hotel on the evening of Monday, September 18. On the Tuesday, delegates and their ladies were entertained at a reception given by the Bourgmestre of Brussels at the Hotel de Ville.

By invitation of the Union des Industries de Métaux Non-Ferreux, a banquet and dance was held at the Concert Noble, Brussels, on Thursday. After the toasts of the King of the Belgians and the Queen of England had been honoured, Mon. de Merre proposed the toast of the Institute of Metals.

Mon. G. Burnay (Chef de Cabinet de Monsieur le Ministre du Commerce Extérieure et de l'Assistance Technique) then proposed the health of all those taking part in the Autumn Meeting. The final toast, that of l'Union des Industries de Métaux Non-Ferreux and the l'Industrie Metallurgique Belge, was proposed by the President, Prof. H. O'Neill.

Tours of Brussels, Bruges, Antwerp and Ghent provided welcome relaxation for the ladies.

Visits to works in the vicinity of Brussels, Antwerp, Charleroi and Liège also took place during the week. These included S.A. Visseries et Trifileries Réunies, Haren (a description of whose plant and processes will be published in our issue of October 13), and S.A. Châssis Métallique Belge (Chamebel).

At this latter works, which specializes in welded aluminium structures, visitors were shown one of the largest anodic oxidation plants in the world.

Other works visited were S.A. Manufacture Belge de Lampes et de Matériel Electronique, which specializes in the field of electronics, thermionic tubes, and transistors, and S.A. Diamant Boart, which manufactures more than 7,000 different types of diamond tools, one of the principal uses for which being drilling bits.

The President, Prof. H. O'Neill, the Autumn Lecturer, Baron Snoy et d'Oppeurs, Col. M.-C. G. A. Berger-Hainaut, Mr. R. E. Moore

The Bourgmestre of Brussels, and Madame Cooremans with the President Prof. H. O'Neill

Descriptions of the plant and processes of three other works which were visited, Société Général Métallurgique de Hoboken S.A., at Olen, Société des Mines et Fonderies de Zinc de la Vielle-Montagne, at Balen, and S.A. Phenix Works at Flémalle, appear on pages 277, 273 and 281 respectively of this issue.

Some delegates were also able to inspect the Centre d'Etude de L'Energie Nucléaire, where they were shown the experimental reactor (BR1) completed in 1957, and two others (BR2 and BR3) now nearing completion. Particular interest was shown in the new laboratories for the development of nuclear techniques especially in the medical, biological and agricultural fields.

An account of the work at the Centre National de Recherches Métallurgiques, which is supported by both the non-ferrous and the iron and steel industries and which has as its objects the improvement of manufacturing methods in the metallurgical industry and of the quality of finished products, and the development of new applications of metallurgical products, will appear in next week's issue of METAL INDUSTRY.

Outside those of purely non-ferrous interest were the works of Cockerill-Ougrée S.A., a highly integrated iron and steel manufacturing unit with blast furnaces, steel furnaces and rolling mills. An electrolytic tinplate line has recently been installed and there is also a plant for galvanizing steel sheet.

Also visited were the Fabrique Nationale d'Armes de Guerre, S.A., Herstal, which not only manufactures small arms and ammunition but also trolley buses and engines for jet aircraft; and S.A. des Ateliers de Constructions Electriques de Charleroi, manufacturers of nuclear power plants and power stations.

Guests at the reception given by the Bourgmestre of Brussels at the Hotel de Ville

TECHNICAL SESSION

Deformation and Fracture

WITH the President, Prof. H. O'Neill, in the chair, the first technical session, held on the morning of Tuesday, September 19, was devoted to a discussion on the general theme of Deformation and Fracture, based on the following Papers. "The Tensile Properties of Heavily Deformed Molybdenum after Neutron Irradiation", by D. N. Sethna, A. A. Johnson, K. J. Proud and S. S. Sheinin. "The Recovery and Recrystallization of Copper and Aluminium Under Stress", by P. H. Thornton and R. W. Cahn. "The Deformation of Single Crystals of Aluminum-4·5 per cent Copper Alloy", by G. Greetham and R. W. K. Honeycombe. "Creep and Hardness of Metals: A Physical Study", by T. O. Mulhearn and D. Tabor. "The Role of Voids in Creep and Fracture of a Pure Metal", by P. W. Davies and J. P. Dennison. "An Electron-Microscopic Study of a Cobalt-Base Alloy", by L. Habraken. "The Phase Transformation of Thin Cobalt Films", by E. Votava.

The Papers were presented by **Dr. Ivor Jenkins,** acting as Rapporteur. In the course of his remarks Dr. Jenkins said :—

During the past several years the meetings of this Institute, and the metallurgical literature in general, have indicated the ever-growing volume of scientific research which is being applied to the study of the basic properties of metals, and the attempts which are being made to explain these properties in terms of fundamental parameters. In particular, those properties which are sensitive to structure, such as recovery, recrystallization, deformation and fracture, have come in for considerable attention. The dislocation, perhaps even to the most Victorian of metallurgists, is no longer a theoretical concept, and the remarkable advances in electron microscopy now enable it to be seen. It has been described as the elementary unit of plastic flow, and the properties of the metal around such a lattice disturbance are of primary importance in determining its behaviour. But even as the atom of Dalton has ceased to be universal and the ultimate particle, so we are now taught that there are different types of dislocation; that they can dissociate into partial dislocations with associated stacking faults, and that the intrinsic energy of such faults may be a fundamental parameter affecting a number of properties. We are told also that dislocations may interact either to annihilate one another or to produce some other form of lattice defect, such as a vacancy or even the nucleus of a crack; they may also interact with vacancies, grain boundaries, solute atoms and with precipitates, the nature of the latter reaction depending upon whether the precipitate is coherent or not with the lattice of the matrix. It is the outcome of such interactions as these which may profoundly affect the basic properties of metals.

It is, then, against this tangled web of the detailed structure of metals that the group of Papers assembled for discussion today must be viewed. They differ widely in subject matter, but all are concerned with structure-sensitive properties of metals and the interpretation of deformation and fracture behaviour in terms of what may be called the "fine" structure of metals. In presenting them on behalf of the authors, I have arbitrarily divided them into two groups, those primarily concerned with deformation and related effects, and those concerned with deformation and fracture.

The Paper by Thornton and Cahn is not concerned with deformation *per se*, but their studies of the effect of stress upon the kinetics of recovery and recrystallization lead to interesting observations on the deformed and recovered structures. Using hardness changes as a measure of the degree of recovery and of recrystallization, specimens of super-pure aluminium and of three grades of copper of very high, but varying purity, were cold worked by tensile deformation and then isothermally annealed whilst being subjected to a tensile creep stress. The effect of stress on the rate of grain growth was studied on single crystals of the pure aluminium and on polycrystalline copper with a sharp, twin-free, cube texture, to ensure growth into neighbouring regions of uniform deformation and orientation. Work hardening was achieved by cold rolling the gauge length of miniature tensile test specimens and nucleation was promoted by scratching the gauge length with a hardened steel point under a fixed load, in a direction normal to the specimen axis.

Stress enhances the recovery of aluminium, but whilst a slight recovery could be detected in the less pure (O.F.H.C.) copper on annealing in the unstressed state, application of stress completely suppresses this, and in all grades leads to an increase in hardness.

The difference in the recovery of the two metals is attributed to the relative ease with which dislocations dissociate into partials. The stacking fault in aluminium is short, and this facilitates recovery by climb and polygonization when vacancies are generated during the creep process. In copper, the partials are more widely separated and this process does not occur so readily; hence, recovery cannot take place. The increased

D. N. Sethna

A. A. Johnson

S. S. Sheinin

P. H. Thornton

R. W. Cahn

recovery of the less pure grades of copper is attributed to the greater ease of polygonization in the presence of an impurity, but no explanation can be provided for this.

The experiments on nucleation and grain growth showed considerable scatter for both materials, and the conclusions reached are, therefore, only qualitative. With this reservation, however, it is believed that stress has little effect upon the mean rate of grain growth in the aluminium, but that the rate of nucleation is profoundly reduced. The only conclusion that could be drawn from experiments with cube texture copper is that despite its many grain boundaries, the small misorientation appears to be unfavourable to nucleation, and this clearly merits further investigation.

The effect of stress upon recrystallization of aluminium shows that two softening stages are apparent, the first due to recovery and the other to recrystallization. Whilst the effect of stress, apparently, is to accelerate the rate of recrystallization, the authors conclude, from their metallographic studies, that the increased rate of softening is due almost entirely to the stress-enhanced recovery. Because of this, recrystallization was very much reduced and even, in some cases, inhibited.

In the absence of a reliable metallographic technique for distinguishing recrystallized from non-recrystallized regions in copper, progress of recrystallization was followed by microhardness histograms, and this technique could be used only on the purest grade of copper. The histogram splits into two well-defined peaks for material annealed in the unstressed condition, and the effect of an applied stress is to move the "soft" peak towards the "hard" peak and to reduce the scatter. This is attributed to the further work-hardening of the recrystallized material resulting from creep deformation under the applied stress, and further recrystallization is only induced at the highest stress level.

Much of the past work on deformation has been done on single crystals of pure metals, and accordingly it is interesting to find the paper by Greetham and Honeycombe introducing us to the deformation behaviour of single crystals in an aluminium-4·5 per cent copper age-hardening alloy.

High purity, single crystals produced by the strain-anneal method, were heat-treated to produce four different structural conditions, namely: supersaturated solution; aged at 130°C. for 2 days to produce G.P. [1] zones; aged at 190°C. for 27½ hr. to give optimum hardness with coherent G.P. [2] zones and a coherent θ' precipitate; and finally, over-aged for 2 days at 350°C. to give a coarse dispersion of $CuAl_2$ precipitate. The deformation characteristics of the different structures were followed by a study of the flow stress and rate of work-hardening at 77°K. whilst the effects of interrupting the deformation both at 77°K. and 293°K. were also examined.

Stress-strain curves at 77°K. show that the supersaturated solution is markedly different in behaviour from the two aged materials having a low flow stress, no yield point and a low rate of work-hardening. The sharp change in the curve at the flow stress, however, is considered to be indicative of some dislocation locking which is attributed to the clustering of solute atoms on dislocations. Material aged at 130°C. has three times the flow stress and this is considered to be due to the G.P. [1] zones lying on {001} planes forming pegs on dislocation lines and, because of their close spacing, producing effective locking. The dislocations, however, can cut through the zones and form a passage for subsequent dislocations, so that there is little work-hardening. This view is supported by the straight, well-defined slip bands in this material. The flow stress in this material is higher at 77°K. than at 293°K., and is attributed to the short range interaction at the lower temperature between dislocations and the G.P. [1] zones.

The high flow stress at 77°K. of material aged at 190°C. suggests that dislocation locking is as strong as in the material aged at 130°C. However, the former material shows a marked rate of work-hardening, indicating that the movement of dislocations is more difficult; the corresponding slip system is not so well-defined. The authors say that this is primarily due to a change in spacing of the precipitated particles (now about 400 A) so that dislocations bow around them by the Orowan mechanism, even though the particles are still coherent with the matrix. This view is supported by the fact that the flow stress is similar at 77°K. and 293°K.

The wider separation of the particles in the over-aged material leads to a lower flow stress, but the rate of work-hardening is high because of interaction between dislocations and the distorted areas near to the particles. Deformation was associated with an octahedral slip system which was particularly pronounced when the material was heavily deformed at 293°K.

Supersaturated crystals tending towards symmetrical orientations showed higher rates of strain hardening than those of other orientations, but the effect became less pronounced as the degree of ageing increased.

Whilst the supersaturated material and that aged at 190°C. showed a similar flow stress at 293°K. as at 77°K., material aged at 130°C. had a much lower flow stress at 293°K. Also, the rates of strain-hardening for the supersaturated solution and the material aged at 130°C. increased markedly at 293°K., indicating that strain-ageing was being induced by the increase in diffusion of copper atoms resulting from the higher concentration of dislocations and vacancies. Neither of the other two materials showed any dependence of work-hardening on temperature.

Interruption of the deformation, and, in particular, the inclusion of a rest period at a temperature higher than the test temperature, led to a permanent raising of the stress/strain curve, but without significant change in the rate of work-hardening. This evidence of strain-induced ageing was found in all the heat-treated states, the effect being most pronounced in the supersaturated material. It is concluded that the upward shift is due to precipitation on to existing dislocations; this masks a degree of solute-atom hardening which also affects the flow stress, and, in the case of the over-aged material, leads to a Cottrell-locking effect, without a raising of the stress/strain curve. Strain-induced precipitation occurs in material aged at 130°C. and at 190°C., indicating that the solid solution remaining is still supersaturated.

Mulhearn and Tabor remind us that whilst the stress and strain patterns around a hardness indentation are complex, the mean pressure over the indenter is a fairly direct measure of the yield stress of a metal, and the work-hardening index, x, can be directly related to Meyer hardness index n:

$$x = n - 2$$

For metals which do not work-harden significantly, $n = 2$; for those which harden appreciably, $n = 2{\cdot}6$. Maintenance of the load in the hardness testing of soft, low-melting point metals results in some relaxation of the mean pressure over the indentation, due to creep. The authors have studied this effect on indium and on lead over a wide temperature range and for loading times from 10^3 to 10^{-4} sec.

For the longer loading times, a standard Vickers hardness machine was used, but for times less than 20 sec. a special flexible, low-inertia, spring machine was designed which permitted loading times down to 1 sec. Still shorter loading times were achieved with a heavy ballistic pendulum and with a free-falling ball.

Almost all indenters were hard-steel spheres. The indium and lead were spectrographically pure and, excepting for a few preliminary experiments on polycrystalline material which gave considerable scatter in results, all the experimental work was done on single crystals.

Results for both metals, plotting the logarithm of the mean pressure against the logarithm of time, show that at temperatures greater than $0{\cdot}6T_m$ (T_m = melting point), and for loading times longer than about 1 sec., a series of parallel lines is obtained, each corresponding to a particular test temperature.

On the assumption that the mean indentation pressure is

directly related to stress and that strain can be expressed as a linear function of the indentation and indenter diameters, the authors show mathematically that if the load, temperature and indenter are maintained constant, log p should bear a linear relationship to log t. The displacement of one line from another is then shown to be a measure of the activation energy of the process; for indium, this has been calculated as 16 K.cals., whilst for lead, the corresponding value is 28 K.cals., both values being close to the respective activation energies of self-diffusion. It is concluded, therefore, that these portions of the diagrams correspond to a viscous-creep range. Deformation is by slip, with no evidence of recrystallization, and the rate-controlling process is believed to be that of dislocation climb.

For loading times less than 1 sec., the straight line relationship breaks down and all curves converge to an upper limiting value, P max., at a loading time of 10^{-4} sec. and less, which is independent of the test temperature. In indium, the type of deformation also changes from one of slip to twinning. At the temperature of liquid air, hardness is almost independent of loading time and is about equal to P max.; deformation is again by twinning. In this region, the steep nature of log p/log t curve implies only a relatively small activation energy in the transition from twinning to slip.

Over the range of temperatures and loading times used, deformation in lead appeared to involve only slip; at very low temperatures or for short loading times, a recovery process appears to supersede that of self-diffusion.

The two Papers from Belgium remind us of the great advances which have been made in electron microscopy in the last few years in providing direct evidence of the finer structure of metals. Votava has studied the phase transformation in high purity cobalt, by direct transmission electron microscopy of thin films, about 1,500 Å thick. A special specimen holder enabled the film to be heated to about 900°C. inside the microscope.

The room temperature, h.c.p. form, produced by annealing and slow cooling from 900°C. before electrolytic thinning, shows extensive stacking faults. On heating, these begin to disappear at about 450°C., and the coalescence of partial into whole dislocations transforms h.c.p. areas into f.c.c. On cooling, the process is put into reverse, and transformed areas are associated with the splitting of dislocations into partials and the appearance of long stacking faults. However, unlike bulk specimens, the thin films show a lowering of the transformation temperature on cooling and a partial retention of the f.c.c. structure as shown by the lower density of stacking faults.

It is concluded that on heating above the transformation temperature many of the total dislocations formed from the partials are either lost at grain boundaries or become pinned at obstacles. On cooling, there is therefore a much lower density of stacking faults having common pole dislocations with a screw character, which is the transformation mechanism proposed by Seeger, and only a small part of the matrix is transformed to h.c.p. The large, super-cooling effect is attributed to the pinning of dislocations on both surfaces of the very thin film, which interferes with their dissociation into partials.

Habraken has applied the same technique to a study of the effects of cold deformation and heat-treatment on the fine structural features of a heat-resisting alloy containing 50 per cent cobalt, 27 per cent chromium and 23 per cent iron. Earlier work on this and similar systems has shown that the iron-chromium and chromium-cobalt sigma phases are isomorphous and that the transformation of the h.c.p. (epsilon) phase to the high temperature gamma form occurs at a higher temperature in the ternary alloy than in pure cobalt. Furthermore, between 600°C. and 700°C. a four-phase interaction takes place

$$\gamma + \sigma \rightarrow \epsilon + \alpha$$

For the alloy studied in the present Paper, the equilibrium condition at 1,200°C. is γ and below 800°C., γ and σ. At the four-phase transformation temperature, the alloy composition lies at the boundary between the $(\gamma+\sigma+\epsilon)$ and the $(\epsilon+\sigma)$ fields.

The $\gamma \rightarrow \epsilon$ transformation in pure cobalt and in the present alloy is of the martensitic type and even severe quenching from the γ field fails to suppress it. The present work has shown that prolonged ageing at 800°C. results in the precipitation of sigma particles, mainly in the ϵ phase and at grain boundaries.

The effect of rate of cooling after annealing at 950°C. and at 1,200°C. has been studied. Coarse-grained material, resulting from the higher annealing temperature and from slower cooling rates showed considerable transformation to the ϵ phase, with many wide stacking faults appearing in both the γ and ϵ phases. The ϵ phase in material air cooled from 1,200°C. also showed a regular array of dislocations. Heat-treatment of the annealed alloy at 700°C. produced no precipitate; the γ phase showed wide stacking faults, whilst ϵ phase showed stacking faults limited by partial dislocations. Cold deformation of the annealed alloy showed a very large number of stacking faults along the three (III) directions in the γ phase, whilst the detail of the ϵ regions could not be resolved. After prolonged annealing at 700°C., however, the deformed ϵ structure transformed into precipitates of σ at triple boundary points and at a large number of small stacking faults within the grains, the stacking faults in the γ regions remaining unchanged. σ phase also appears in the γ grains.

On the basis of the work described in this Paper, it is concluded that the high temperature (850°C.) strength of the alloy is due to the low energy stacking fault structure resulting from the segregation of solute atoms between the dissociated dislocations. In this way, cross slip, climb and intersection of dislocations are made difficult. At higher temperatures, the strength is retained by a precipitation of a stable σ phase, associated with the stacking faults within the grains.

Davies and Dennison take us further along the road of deformation and describe their experimental work aimed at explaining the mechanism of the formation of voids on grain boundaries during creep, which leads to intergranular fracture. They have studied the creep and rupture behaviour of high purity nickel in the form of void-free vacuum cast bar; and two sintered materials having, respectively, 1 per cent and 3 per cent by volume of closed porosity. Tensile creep tests were carried out at 400°C., 500°C. and 600°C. At 600°C., porosity markedly reduced rupture life at the higher stresses, whilst at low stresses all materials were similar. At 500°C., the stress-rupture life was little different for all three materials, but at 400°C. both materials having pre-existing voids gave much inferior life at a given stress. In contrast to the variability in rupture life, the three materials are stated to behave similarly at a given temperature with respect to stress/creep rate relationships. In all cases, creep rate could be related to rupture life by the Monkman and Grant relationship

$$\log (\text{time to rupture}) + m \log (\text{minimum creep rate}) = C.$$

The total elongation in all tests was within the range 10-15 per cent, increasing with an increase in the applied stress. Grain growth was extensive at 600°C. and low stresses, in the void-free nickel, whilst at higher stresses complete recrystallization occurred. At lower temperatures, little change in grain appearance was observed. No grain growth was observed in either of the sintered materials, whilst recrystallization was observed only in the low porosity material at areas of necking and fracture.

The void-free nickel showed signs of internal cracking only at the lower temperatures; presumably, at higher temperatures, stress-relieving effects led to recrystallization and grain growth. Under all conditions of test, both sintered materials showed intergranular cracking, either of the triple point type or resulting from a linking-up of voids. No changes in shape or size of voids remote from the fracture zone could be detected, but in the fracture zone and at grain boundaries a change in shape could be observed.

The authors conclude that since the time to fracture and minimum creep rate are similarly related for all specimens, the

R. W. K. Honeycombe

T. O. Mulhearn

D. Tabor

P. W. Davies

J. P. Dennison

L. Habraken

E. Votava

most significant contribution of voids to the fracture process is their effect on creep rates. This cannot be accounted for by the reduction in effective cross-sectional area, neither can it be associated with different sub-structures in the three nickel grades before test, since sub-structures in a metal of low stacking fault energy, such as nickel, are only developed after lengthy times of creep testing.

Mott has proposed that the rate-controlling process for creep is the rate at which vacancies are created by the movement of jogs on screw dislocations and absorbed into the metal lattice. The authors have adapted Mott's equation to the condition where a non-equilibrium concentration of vacancies exists in the lattice, and show that the presence in a metal of a large number of vacancy sinks, such as voids, would be expected to increase the creep rate by drawing off a large quantity of vacancies and hence change the activation-free energy for creep. In support of this view, the authors show that under compression, the creep rate is independent of pre-existing voids which are unstable and no longer act as vacancy sinks.

The product of time to fracture and minimum creep rate is approximately equal to the total creep elongation neglecting the initial and final rapid extensions and since the relationship between these two parameters is independent of stress, temperature and the presence of voids, this suggests to the authors that all material tested is capable of only a fixed amount of true creep elongation. Once this is attained, voids in dense material are created at grain boundaries by a slip mechanism, grow to a stable size and then proceed to absorb vacancies from the lattice with a resulting increase in creep rate, and an increase in the rate of growth of cracks by further boundary slip. Pre-existing voids do not materially change this mechanism, since the effect of grain boundary slip is merely to change their shape and not their volume. Vacancy absorption, therefore, is not considered to be an important mechanism in the growth of voids.

Thus, at 600°C. and low stresses, the time is sufficient for vacancies to diffuse to all available sinks, and then the addition of extra voids is unimportant. Only at higher stresses and tests of shorter duration do pre-existing voids become important. At 500°C., the effect of voids in restricting grain growth is thought to cancel their effect of increasing the creep rate by vacancy absorption. At 400°C., both grain boundary migration and vacancy diffusion are slowed-down and, in the absence of voids, excess vacancies are maintained.

Johnson and co-workers reported upon the effect of neutron irradiation on the ductile-brittle transition in a heavily cold-worked b.c.c. metal, molybdenum. Much of the work devoted to the study of ductile-brittle behaviour in b.c.c. metals has centred around Petch's empirical relationship

$$\sigma_y = \sigma_i + K_y d^{-\frac{1}{2}}$$

and the effects of temperature, strain rate, grain size and impurity content on the terms σ_i (lattice friction stress) and K_y (the stress required to unpin a dislocation from its locking atmosphere). By measuring the effects of neutron irradiation on these two terms, therefore, it should be possible to assess the contributions to irradiation hardening of lattice hardening and dislocation hardening respectively. Work on the irradiation hardening of steel has been interpreted as being due to an increase in σ_i, leaving K_y unchanged. Johnson, on the other hand, in earlier work does not consider that the irradiation hardening of molybdenum can be explained in terms of changes in σ_i and K_y. He believes that the point defects created by neutron irradiation interact with all dislocations present, increasing resistance to slip which results in a higher work-hardening rate and a jogging of dislocation sources so that they become more difficult to operate. If this point of view is correct, then the properties of irradiated molybdenum should depend upon the initial density and distribution of dislocations. The present Paper is an attempt to provide information on this aspect by studying the irradiation embrittlement of heavily deformed molybdenum.

Miniature tensile specimens of molybdenum in three conditions of treatment, namely, swaged at 600°C., stress-relieved at 1,000°C. and annealed, respectively, were sealed in aluminium canisters and exposed at 40-50°C. to neutron doses ranging from 1×10^{19} to 4×10^{19} n.v.t. After an appropriate period to allow activity to decay, the tensile properties of the materials were determined over the temperature range -196°C. to $+100$°C. A constant strain rate of $0{\cdot}88 \times 10^{-4}$/sec. was used.

The temperature dependence of strain to fracture and reduction in area at fracture for the recrystallized and swaged materials is such that in both cases these properties fall sharply with temperature, becoming zero at -60°C. for the recrystallized materials and about -110°C. for the swaged alloy. The yield stress and brittle fracture stresses increased correspondingly, those for the cold worked material being higher at any given temperature than for the recrystallized material. The swaged specimens showed sharp yielding, usually with a yield drop. Both the stress-relieved and the irradiated materials gave similar results to the swaged material, the transition to brittleness occurring at about the same temperature.

The lower transformation temperature of the deformed material as compared with the recrystallized is attributed to a redistribution of grain boundary impurities during working and the removal of grain boundary weakness. Fracture changes from an intergranular one to cleavage, which requires a higher stress and, hence, a lower temperature to induce brittleness. The enhanced yield point in swaged specimens is attributed to a strain-ageing effect resulting from swaging at 600°C., when dislocations in the molybdenum are considered to be mobile.

The absence of any effect of irradiation on the transition temperature is contrary to the results of earlier workers on recrystallized and on stress-relieved molybdenum, but the authors maintain that the results confirm that the effect of neutron irradiation depends upon the initial dislocation structure in the metal. At this stage, they refrain from discussing the implications of this in terms of atomic mechanisms, but bearing in mind the practical significance of the problem in relation to nuclear power plant, advocate a more detailed study of the extent to which irradiation embrittlement may be affected by control of the initial dislocation structure in a metal.

Discussion

The discussion was opened by **Dr. G. L. J. Bailey** (International Nickel Company (Mond) Limited), who said the Papers to be discussed lie, in the main, within the field of metal physics, that is to say, that they are concerned with atomistic interpretations of macroscopic observations. All the work reported, therefore, comes into the "fundamental" category and no one will expect that the results should lend themselves directly to the solution of their particular practical problems. The metal physicists have a difficult bridge to build, but if we can feel that they are building it towards the technological shore, they can be assured of the interest of the general membership of the Institute. I think it is appropriate, therefore, to look at each Paper critically from this point of view and ask how far the work described brings us closer to some technological advance. This surely is the aim of metal physics as it comes within the purview of the Institute of Metals.

The arrangers of this session have grouped the Papers we are discussing under the heading "Deformation and Fracture". This is a neat wrapper for a package of widely assorted contents, and it is not easy at first sight to find common threads running through the different investigations reported. It is worth noting, however, that only two of these seven Papers are explicitly concerned with alloys. The rest cover a broad spectrum of pure non-ferrous metals — copper, cobalt, nickel, aluminium, lead, indium, and molybdenum—of which probably only the last, molybdenum, can be said to pose problems of practical interest, as a pure metal, from the point of view of deformation and fracture.

I know it is argued that one must build up an understanding of the complex from studies of the simple, but I do find it rather difficult to see how studies of a pure metal, of the kind described, for example, by Dennison and Davies, are going, even in the long run, to contribute to an understanding of the relevant mechanisms of creep in the complex alloys which are of greatest practical interest in a creep context, and I feel the same kind of difficulty about the Papers by Tabor and Mulhearn and by Cahn and Thornton.

One has only to read the Paper by Honeycombe and Greetham on the deformation of aluminium-4½ per cent copper to see that important new factors assume an overriding influence on deformation in a real engineering material.

Is the detailed quantitative sort of approach, using pure metals, exemplified by the three Papers I have mentioned, really going to produce a significant advance in technology?

The Paper by Mulhearn and Tabor returns to the tradition of the early, classical work of Andrade in that, initially, they describe the process of deformation in analytical terms, without

a physical model. There have frequently been suggestions that hot-hardness tests can be correlated with conventional creep data, with varying degrees of empiricism. However, hardness impressions impose a complex type of deformation and it is easy to agree that the analysis of plastic processes given in the Paper is an essential step in putting such correlations on a firmer basis. It is a pity that their work has been confined to pure metals.

I hope the authors will be able to say that they will extend their work to more complex materials, and in particular to precipitation-hardened alloys. Some of these show stress-strain relationships which could not be described by the simple law given in the first paragraph of their Paper. Examples of such curves are given in another Paper under discussion—that of Greetham and Honeycombe. It would be interesting to know how sensitive is the analysis given by Tabor and his colleague to the shape of this stress-strain curve, or the creep curve.

Can we, in fact, begin to see how far hot-hardness measurements, properly interpreted, may be of practical use as a quick-sorting method in the development of creep resistant alloys?

Turning now to the Paper by Greetham and Honeycombe, we see the application of some current ideas about dislocation movement to the interpretation of plastic deformation in single crystals of an aluminium-copper alloy.

The heat-treatments examined produce such marked effects on the stress-strain curve that there is ample scope for several different aspects of dislocation theory in explaining them.

The authors also find it necessary to distinguish rather subtle differences between "strain-ageing", particularly in certain of their over-aged crystals, and "strain-age-hardening" in, for example, the supersaturated solid solutions. How far do these concepts differ? The precipitates of strain-induced hardening may well be the clusters of copper atoms which form the G.P.I. zones. Will these differ much from the concentrations of what will presumably also be copper atoms involved in strain-ageing by the Cottrell mechanism?

Is Suzuki hardening, in the form of segregation of copper to the stacking faults of extended dislocations, a possible alternative hardening mechanism?

Davies and Dennison show some interesting results in Figs. 4, 5 and 9 of their Paper. I would like to feel more fully convinced that the differences of creep behaviour between the different types of specimen used are not in some way connected with minor impurity differences, but assuming that purity is not a factor there is something to be explained.

As I understand it, the authors say, following Mott, that the resistance to the movement of jogs on screw dislocations is the rate determining process in the creep of pure metals. The movement of jogs produces vacancies, and vacancy concentration in creep will normally be above equilibrium. The higher the vacancy concentration, the more difficult it is for new vacancies to form and, therefore, the greater the resistance to deformation. If voids are present, they provide highly efficient vacancy sinks, so creep rate is increased.

This last is the most difficult premise to accept. Lomer, in the "Symposium on Vacancies and Other Point Defects in Metals and Alloys" of 1958, makes the point that free surfaces, grain boundaries and dislocations all provide not only *sinks* but also *sources* for vacancies, so there are plenty of places, apart from the voids, for vacancies to go to, as well as to come from.

Of all the Papers we are discussing, I must confess that I found the Paper by Thornton and Cahn to be the least provocative of interest in relation to any technological problem of which I am aware. That is not to say that the difficult task they have set themselves has not been well and carefully carried out. If their conclusions are of more than pedantic interest, I hope that the discussion will bring the point out, and also, of course, give opportunity to air any academic questions that the Paper may provoke. As in the Paper by Habraken, the authors emphasize the importance of stacking fault energy, in that they ascribe the differences in behaviour between copper and aluminium to the relatively low stacking fault energy in copper.

The Paper by Sethna, Johnson, Proud and Sheinin is brief and to the point. The result they obtained is perhaps not surprising, and is, no doubt, of direct practical consequence.

Both Belgian Papers describe studies made using the electron microscope to examine thin metallic films, and from this point of view of the practical significance of the observations, it has to be said that thin films are a different thing from the three-dimensional material they represent. Indeed, Votava's Paper makes this quite clear. The point is not, however, explicitly dealt with by Habraken in his interesting discussion and conclusions. Apart from the two-dimensional qualifications which have to be borne in mind, there is, in the case of alloys, the possibility that the thin film specimen is not compositionally representative of the bulk, and I would like to ask Habraken how far those of his conclusions which are based on observations of thin films can, in his opinion, be applied reliably to the alloy he has studied when in its normal three-dimensional form.

I would like to add that, whether or not one can quantitatively translate thin-film observations into three-dimensional practice, I am sure that the *qualitative* findings are enormously stimulating to practical alloy development.

S. Harper (British Non-Ferrous Metals Research Association): Quite large differences in the minimum creep rate and "time to fracture" between sintered and melted nickel have been found by Davies and Dennison. They ascribe these differences as being due to grain boundary cavities left unsintered in the sintered material, the cavities acting as sinks for vacancies which are generated by the creep process. It appears that this sintered material does not fail by the growth and spread of the cavities along the grain boundaries. The cavities do not grow in size, and failure is by the formation of a long, very narrow crack along the grain boundaries. One wonders whether the cavities, as such, play any part in the creep process. It is difficult to see why isolated cavities should be such better sinks than the grain boundaries themselves, and the time involved in the process appears to be quite wrong. Assuming that the activation energy for the movement of a vacancy in nickel is approximately 1·3 eV (A. H. Cottrell; "Symposium on Vacancies and other Point Defects in Metals and Alloys", The Institute of Metals, 1957, p. 11), then the time for a substantial number of the vacancies to move across a grain is about 10^5 to 10^6 sec. at 400°C.; a time which is long compared with the time to fracture in many of the tests. Moreover, if the rate controlling process is the diffusion of vacancies to a grain boundary, this process should still go on in the absence of voids and, hence, the creep rate should increase with decreasing grain size which, as the authors point out, is contrary to experience with nickel in this temperature range (Hazlett and Parker; *J.A.I.M.M.E.*, 197, 318, 1953).

It seems more likely that vacancies generated during creep are annihilated on dislocations or on the interstitials which are also formed—as first suggested by Mott. I wonder whether

Fig. 1—Cavities in copper produced by water quenching from 650°C. ×100.

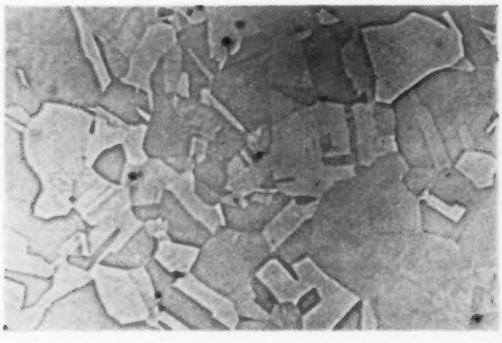
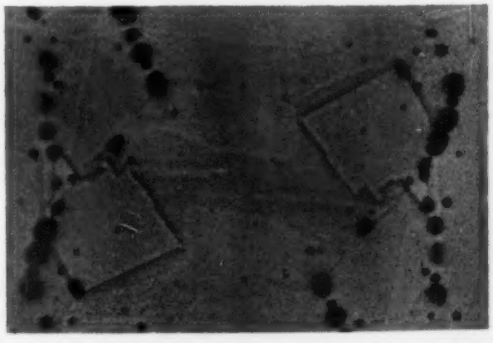


Fig. 2—Specimen as Fig. 1 stressed at 150 lb/in² at 900°C. for 60 hr. ×100.



the authors have considered that the results may be due to the presence of grain boundary films of some contaminant and it is this film which stops the cavities sintering up.

Evidence that the cavities, even when sheared by grain boundary sliding, do not return to a spherical shape, suggests that the surface of the cavities and the exposed grain boundary surface may be contaminated. Again, the complete absence of grain growth at 600°C. suggests that such films do exist. Some restraint to grain growth is offered by the cavities, but in our experience clean surfaced cavities produced internally in copper do not markedly restrict grain growth at 500°C. It could be that the grain boundary film cracks under a tensile stress and it is the time dependent spread of these cracks which gives a macroscopic acceleration of creep in tension but not in compression. Can the authors tell us whether they have examined the grain boundaries for cracking at intermediate stages in the creep test?

We would support the authors in their contention that the condensation of lattice vacancies is relatively unimportant as a mechanism for the growth of voids. We have recently carried out some tests which seem to show this. The Russian scientist Rybakova and associates (L. M. Rybakova and S. Z. Yemel'chik; "The Physics of Metals and Metallography", 1960, 9, (5), 89-96) have shown that small grain boundary cavities can be produced in copper by cyclic quenching. Fig. 1 shows such cavities produced by quenching copper from 650°C. into water a hundred times. The mechanism by which these cavities are produced is not yet fully understood but it is clearly connected with the internal strains produced on quenching. The phenomenon does, however, provide a very simple method of producing small grain boundary cavities internally, so that the voids are not contaminated either with gas or surface corrosion films. These cavities can be made to grow under very low stresses at high temperatures. Fig. 2 shows the results of stressing such a specimen at 150 lb/in^2 at 900°C. for 60 hr. The cavities have grown and are beginning to join up and form a fracture. This low stress is far too small to cause significant deformation so that vacancies cannot come from that source and are, presumably, supplied from grain boundaries parallel to the tension axis. The applied stress is, however, just sufficient to overcome the surface tensional forces of cavities of about 2-3 microns diameter.

Belgian Non-Ferrous Metals Industry

By Marcel de Merre

(*President, l'Union des Industries de Métaux Non-Ferreux*)

FROM the time when the metallurgy of non-ferrous metals had attained the industrial stage it has always formed one of the main basic sections of the Belgian economy. The production of zinc, lead and silver dates back to the beginning of the 19th century. It was, incidentally, a Belgian, J. J. D. Dony, who discovered the process for the production of zinc, which subsequently was adopted throughout the world.

With an output of 200,000 metric tons, the Belgian works, before the 1914 war, occupied third place among the smelters of the world.

Later, the activities of the Belgian smelters were directed more and more towards the production of higher and higher grades of zinc and lead as well as towards the recovery of other non-ferrous metals such as cadmium, antimony, bismuth and arsenic, which generally accompany these metals, and towards chemical products arising from these smelting operations.

On the other hand, the exploitation of the mineral resources of the Congo led to the production in Belgium of a number of important metals such as copper, cobalt, radium, tin, gold, silver, selenium, germanium, uranium, tantalum and niobium. These metals are today being produced in works which are among the largest and most modern in Europe.

Paralleling the development of the production of the various non-ferrous metals was the formation of an important metal-working industry, primarily concerned with zinc, copper and lead, and the development from the years before the second world war of the fabrication of aluminium.

To complete this outline of the structure of the Belgian non-ferrous metals industry, mention must also be made of the secondary alloy smelting works and foundries.

The whole of the Belgian non-ferrous metals industry, the concentration of which is unique, finds itself for various obvious reasons primarily concerned with international trade, both import and export.

With no mineral resources available within the country, the Belgian smelters must procure their raw materials from countries throughout the world. The relative shortage of ores available, particularly those of zinc and lead, which results from the siting of smelters at the mines, calls for continuous efforts in the field of raw materials supply. This has led the Belgian smelters to form the Association de Recherches Minières, the prospecting activities of which were intended to lead to the discovery of new sources of supply.

On the other hand, the home market absorbing only 30 per cent of the output, the bulk of the country's production has, therefore, to be exported.

It is around the above two features that the problems, the preoccupations and the hopes of the Belgian non-ferrous metal industry are centred.

Economic Aspects

Because of the almost complete range covered by its products and the absolute value of the latter, the Belgian non-ferrous metals industry occupies an important position and carries important responsibilities in the national economy.

Comprising some two hundred undertakings and giving employment to nearly 20,000 people, the industry is responsible for about one-tenth of the total Belgian foreign trade. Output of non-ferrous metals for 1960 is given in Table I.

The existence of a large basic industry also ensures a reliable source of supply, competitive conditions and adequate technical assistance to the various consumer fields.

Because of its high productivity and constant progress, Belgian industry has

TABLE I—OUTPUT OF NON-FERROUS METALS IN 1960

Ingot Metals	Output (1,000 metric tons)	Semi-manufactured	Output (1,000 metric tons)
Copper	212	Copper	124
Zinc	248	Zinc and miscellaneous	39
Lead	93	Lead	26
Tin	9	Aluminium	62
Miscellaneous	7		
Total	569	Total	251

been able to maintain its position in the face of foreign competition, which frequently benefits from large home markets protected by heavy customs duties.

This success has only been possible due to the impulse given by the industry to applied scientific research. Its influence has been directed towards the modernizing of the various classical metallurgical processes, the development of entirely new processes, the production of higher and higher grades of metals, the recovery of secondary metals from an ever-growing range of products and, finally, the development of the production of new materials, of which the semiconductive metals have been the most spectacular.

International Relations

The structure of the industry, and of the Belgian economy in general, of necessity ties its main preoccupations to the various aspects of international trade.

Both in regard to the supply of raw materials for the industry and in regard to outlets abroad for all its products, commercial relations with other countries and the policy of partners in trade constitute ever-present problems which condition Belgian prospects of future activities and expansion.

The influence exercised by this particular situation will be better understood from a consideration of the rank occupied by the industry both as a producer and exporter among the countries of the E.E.C. and the O.E.E.C. and the countries of the free world. This ranking is indicated by the data in Tables II and III.

This undoubtedly enviable position also serves as evidence of the difficulties of the daily struggle facing the industry in order to maintain its competitive position in the technical, industrial and scientific and commercial fields, the more so as it finds itself faced by tariffs and trading policies which frequently give rise to unfair conditions of competition.

This applies particularly in the case of the metals fabricating industry which, in foreign markets, meets protective customs duties which are very high and, in some cases, prohibitive and which distort the possibilities for the development of such markets. This situation has, nevertheless, not prevented the fabricating industry from attaining the fifth rank among the O.E.E.C. countries. That is why the various efforts which have been made on an international level since the war with a view to facilitating and liberalizing foreign trade have always received full support from the Belgian non-ferrous metals industry.

Whether in the case of the General Agreement on Tariffs and Trade, of the O.E.E.C. or Benelux, every contribution towards the elimination of foreign exchange restrictions and improvement in the competitive conditions have been considered with favour.

TABLE II—1959 RANKING OF BELGIUM AS INGOT PRODUCER

Metal	In E.E.C.	In O.E.E.C.	In World
Copper	2nd	3rd	7th
Zinc	1st	1st	2nd
Lead	2nd	2nd	6th
Tin	1st	2nd	4th

TABLE III—1960 RANKING OF BELGIUM AS INGOT METALS EXPORTER

Metal	In E.E.C.	In O.E.E.C.	In World
Copper	1st	1st	2nd
Zinc	1st	1st	2nd
Lead	1st	1st	3rd
Tin	3rd	4th	5th

In the same way, the formation of the European Economic Community, which opened the frontiers to a vast market of 160,000,000 inhabitants and placed the producers of the different member countries in equal conditions of competition, could not fail to correspond to the fundamental aspiration of the non-ferrous industry.

In this economic community, the establishment of a common moderate external tariff and the pursuit of a common trading policy will permit the community to benefit from a home market experiencing a balanced expansion, and on the world scale from advantages substantially equal to those enjoyed by the main competitors and trading partners.

The development of this common policy must necessarily be guided by the commercial position of the Six in the world. The considerable proportion of world trade (about 25 per cent) which it claims, constitutes a decisive factor which excludes any question of an isolationist or protectionist policy. There is, likewise, no doubt that the European Economic Community must become a potent factor favouring the lowering of customs barriers throughout the world and the liberalization of trade.

The relations between the Six and the United Kingdom, with its trade relations with the Commonwealth and the European Free Trade Association, present an immediate problem of the greatest importance to the economic future of Europe and the West.

If the countries of the Common Market constitute the largest outlet for the products of the Belgian non-ferrous metals industry (about 50 per cent of its exports), the opening up of other markets, particularly those within the enlarged framework of an economic community, give further promise of general expansion.

While current trade with the United Kingdom and the countries of the European Free Trade Association is, at present, relatively small (about 4 per cent and 16 per cent respectively of Belgian exports) there can be no doubt that an extension of the Common Market frontiers will create new opportunities for development and greater stability.

The special position and structure of the Continental and British non-ferrous metals industries respectively will certainly present various difficulties in regard to commercial policy and tariff controls.

It is to be hoped that these difficulties will be resolved in the course of the coming negotiations in a positive and realistic spirit. Industry itself has a primary roll to play in the search for these solutions.

Whether in regard to commercial policies in their various aspects, or to various factors relating to raw material markets, or in regard to Government or International influences exercised on these markets, the industry, which itself contributes so largely to the state of health of the world markets, cannot remain indifferent to any of these problems.

Future Prospects

The confidence in the future shown by the industry is measured by its achievements in the past.

It rests first of all on the invaluable capital represented by its achievements and on the whole mass of the experience accumulated by industrialists and engineers while facing difficulties and trials in the past.

This confidence is also justified by the potentialities and the variety of the metals manufactured, which permit a constant adaptation of them to new demands and to technical progress. The continuing long-term growth of production and consumption due to the increasing population and the rising standard of living likewise constitute a favourable promise, the more so as the efforts towards international co-operation and economic integration are already bearing fruit.

It is towards this perspective of wider and more liberal horizons that the Belgian non-ferrous metal industry is today directing its hopes.

Autumn Meeting Banquet

Above: Prof. H. O'Neill, Monsieur Marcel de Merre, Monseigneur M. van Waeyenbergh, The Earl of Verulam.

Above: Sir Edgar Sengier, Mme. Leblanc, Mr. G. L. Bailey, M. G. Burnay, Mrs. H. Thomas, M. W. de Keyser, Mrs. L. B. Pfeil, M. J. van Oirbeek

Above: M. G. Leburton, Mme. Brabant, Prof. H. Ford, Mme. Delruelle, Senor F. Torras Serrataco, Mr. J. R. Cotton.

Above: Mme. W. de Keyser, Col. Berger-Hainaut, Mrs. G. L. Bailey, M. F. Leblanc, M. J. Delruelle.

Left. Mme. Berger-Hainaut, M. Brabant, Mrs. H. Ford, Mr. L. S. Ross.

Works Visits

Mines et Fonderies de Zinc de la Vieille-Montagne

IN the metallurgy of zinc and lead, the physical and chemical characteristics of the numerous metals contained in the basic ores have led producers to design and construct integrated installations where dry and wet methods of recovery are united within extremely varied circuits, making it possible to obtain a satisfactory recovery of the many constituents.

This is well illustrated by the plant and processes of la Société des Mines et Fonderies de Zinc de la Vieille-Montagne, which is entering its 125th year of existence and which is, at present, classed as being the largest zinc-producing concern in the world.

Founded in 1837, la Vieille-Montagne, whose head office is in Angleur, near Liège, has expanded considerably since its creation, both as regards the number and size of its working branches and the development and diversity of its products.

Outside Belgium, its mining and metallurgical activity has extended to Sweden, Germany, France and Algeria.

Since 1934, la Vieille-Montagne has entrusted the working of its factories and mines beyond the Rhine to its German branch, "A.G. des Altenbergs für Bergbau und Zinkhüttenbetrieb", at Essen-Bergeborbeck.

The metallurgical undertakings of the V.M. group comprise: two electrolysis plants, five zinc foundries, five rolling-mills, two zinc white works, one lead works and four roasting and sulphuric acid divisions; each of these works has, in addition, a certain number of subsidiary manufactures.

The Balen (Belgium) and Viviez (France) factories have an annual zinc production capacity of 65,000 tonnes and 70,000 tonnes respectively and are the two largest electrolysis plants in Europe.

Although its activity today, as originally, is still based on the metallurgy of zinc, la Vieille-Montagne has gradually been led to increase its manufactures very considerably. Thus, the range of marketable products at present comprises: zinc, lead, cadmium, silver bullion, zinc dust, zinc white, bismuth, mercury, germanium, silicon, indium, thallium, various zinc and lead semi-manufactures, copper sulphate, calcium arsenate, sodium antimonate, and calcium stannate.

The basic materials are mainly composed of zinc and lead ores, oxidized zinciferous materials and metallic zinciferous materials.

The company's objective is to have available adequate technical equipment to treat and to extract as much as possible from any zinciferous or plumbiferous material, whatever its physical state and chemical composition.

Sulphurized zinc ores must be transformed into oxides by roasting, prior to their treatment for the production of metal. The old roasting process, the multiple hearth furnace, is on its way out. It was first of all superseded by roasting in suspension (flash-roasting), then by the very recent process of roasting in a fluidized bed. La Vieille-Montagne has played an important part in the perfecting of this latter technique.

The heat generated by roasting is utilized for raising steam in boilers situated next to the furnaces.

The gases produced, containing 7 per cent sulphur dioxide, are sent, after filtering through cyclones and electrostatic filters, to modern units manufacturing sulphuric acid by the Contact Process. The dusts filtered from the gases furnish a material enriched with lead, cadmium and thallium, which is sent to the cadmium production plant. If the treated ores contain mercury, the sediments collected at the bottom of the wet electrostatic filters are distilled and the mercury thus recovered is purified.

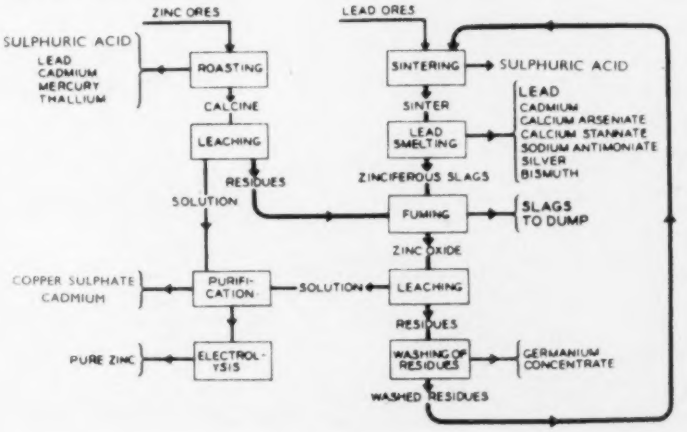
La Vieille-Montagne produces zinc by two different processes, the electrolytic process and the thermal reduction process. As the method of roasting is not the same for ores intended for electrolysis and for those which are to be treated in thermal zinc furnaces, a preliminary selection of the ores takes place before roasting: those which contain valuable secondary metals are treated by electrolysis and those without secondary metals, or containing impurities unsuitable for electrolysis, are reserved for the zinc furnaces.

Those ores for electrolysis are first treated by sulphating roasting so as to compensate for the inevitable acid losses in the electrolysis circuit. For the ores intended for thermal reduction, roasting is carried out so as to eliminate most of the sulphur, and as much as possible of the cadmium and lead, in the form of rich dusts.

This pre-roast is then subjected to a sintering roast on a Dwight-Lloyd machine which, whilst removing the remainder of the lead and cadmium, gives a sintered, dense and porous product which is perfectly suitable for the zinc furnaces.

In general, lead ores contain a little

Fig. 1—Flow sheet of the Balen plant, an integrated zinc and lead smelter and refinery designed to recover by-products. In the closed circuits, by-products are removed at the point where their concentration is at the highest level



zinc and zinc ores a little lead. Consequently, it is usual, after treating each of these ores, for the slag of the lead furnace to be zinciferous (10-13 per cent zinc) and for the electrolysis residues to be plumbiferous.

The complete recovery of lead and zinc, therefore, calls for a closed circuit between the processing units of each of these two metals. A flow sheet of the process, as carried out at Balen, is shown in Fig. 1.

The slag from the lead furnace, and the electrolysis residues, are charged into hot blast furnaces; the product is a rich, mixed oxide containing almost all the zinc and lead of the charge. This oxide, being easily soluble, is put into solution in a circuit separate from the electrolysis of the zinc. The residues from this lixiviation, with lead sulphate base, are sent away to the lead refinery to be put into the charge, after roasting with lead ores. The loop is, therefore, closed and the losses reduced to a minimum.

The mixture, comprising lead ores, rich, lead-containing electrolysis residues from the oxide circuits, plumbiferous materials purchased elsewhere and flux (iron-bearing ashes arising from the magnetic sorting of the residues of zinc furnaces), is desulphurized on the Dwight-Lloyd machine, use being made of the gases for the manufacture of sulphuric acid. The conglomerate obtained, with an addition of coke, is charged into a large water-jacketed furnace of 7·25 m^2 section at tuyère level. For blowing, the furnace has available oxygen-enriched air, the oxygen of which is produced in the factory itself.

The use of oxygen has proved advantageous from the point of view of increased production, reduction in coke consumption and steadiness of furnace running.

The work-lead, with the copper removed when taken from the furnace, is sent for refining by the Harris process. The arsenic, antimony and tin are extracted there in the form of calcium arsenate, calcium stannate and sodium antimonate. After extraction, in the form of a ternary alloy, the gold-bearing silver is obtained by cupellation. The bismuth, partly extracted from the lead, by addition of metals of the alkaline earths, goes into a quaternary alloy with lead base which, subjected to an electrolytic refining operation, gives an extra-pure lead and enriched sludge from which a high purity bismuth is extracted.

The skimmings arising from the removal of copper from the work-lead, liquated and sulphurated in a reverberatory furnace, give an impure, Harris recycled lead, a matte rich in copper and a speiss (arsenide of copper). The 50 per cent copper matte is treated for extraction of the copper in the form of copper sulphate.

The electrolysis residues, poor in lead, are first of all briquetted, mixed with some carbon and without any binder in compacting presses. These conglomerates, either alone or mixed with slag in lumps from the lead furnace, are then charged with some coke into the oxygen-enriched hot blast furnaces. The advantages of oxygen-enrichment of the air have proved to be as great as in the lead furnace.

As by-products, iron-copper mattes are obtained as well as a slag practically free from non-ferrous metal values and which constitutes a raw material for the manufacture of cement. The oxide collected by filtering the gases is then sent to be put into the zinc electrolysis solution.

Electrolytic Zinc

The impure solutions obtained by lixiviation of the roasted ores, cupola oxides and various other oxides purchased, have to be purified. In fact, they contain, in addition to zinc, the following soluble elements: copper, cadmium, germanium, nickel, cobalt, arsenic and antimony. Purification is carried out mainly with the aid of zinc dusts (produced in the zinc furnaces). This purification gives a residue rich in cadmium and a copper cement, which are used for the manufacture of cadmium and copper sulphate respectively. A special purification for germanium gives a basic concentrate for the manufacture of this metal.

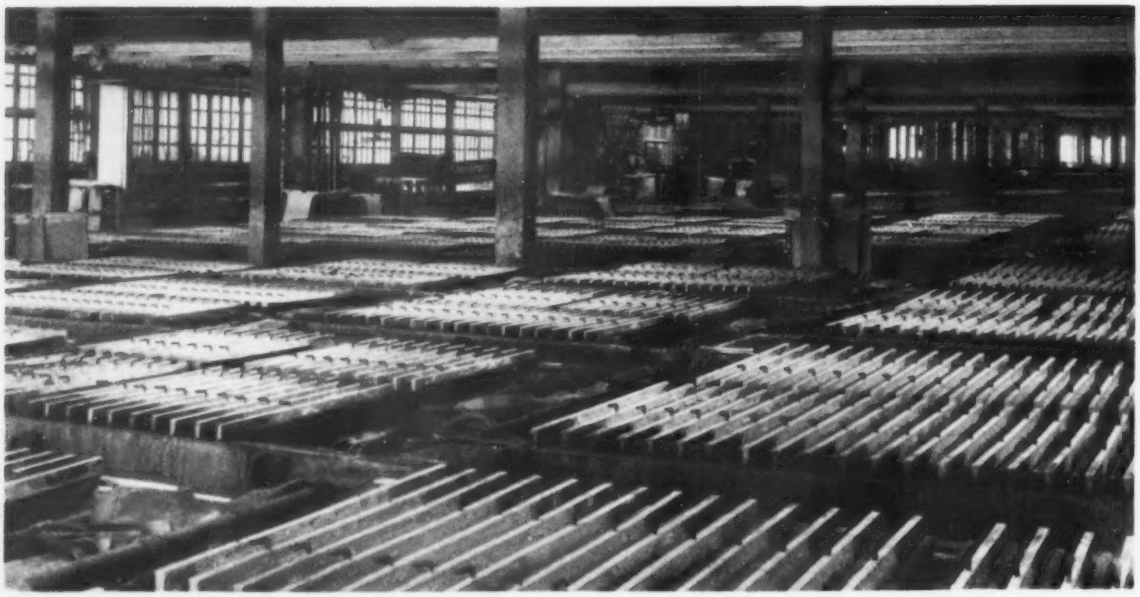
The purified solution is finally electrolysed in cells with argentiferous lead anodes and aluminium cathodes. The zinc cathodes obtained, of 99·99-99·995 per cent and more purity, are resmelted in electric induction furnaces and cast into ingots in an automatic ingot casting machine, provided with an automatic feed device of original design.

Finally, at Balen, an autonomous central electric station with a power of 55,000 kW supplies the energy required for electrolysis and for the other divisions in the factory.

Compared with electrolysis techniques generally known and practised, those of Balen and Viviez can be differentiated by the following characteristics:

(1) Ability of the solution and refining processes to accommodate sudden and repeated variations in the contents of impurities of all types, called

General view of the electrolytic zinc installation



for by the very varied chemical compositions of the supply materials.

(2) Automatic functioning of the various solution circuits by means of *p*H regulation meters.

(3) Rejection of any residue or any liquor, but full recovery of the valuable elements.

(4) Time of cathodic deposit of long duration (48 and 72 hr.), with high ampere output and consumption of about 3,200 kWh/tonne of cathode.

(5) Use of horizontally grooved lead-silver anodes, making it possible to reach, without addition agent, a lead content less than 30 gm/tonne in the zinc produced.

Cadmium

In spite of the relatively low content of cadmium in the original materials, the various gas filtration dusts and the solutions arising from the retreatment of the zinc electrolysis purification residues, are sufficiently rich in cadmium to make possible the production of pure metal, after various phases of sulphating, lixiviation and cementation, either electrolytically or thermically, the two processes being worked by both electrolysis plants.

Thallium, generally present in solutions of cadmium during its extraction process, is finally separated from the latter during the purification of the cadmium-bearing solutions by chromate precipitation. After various treatments, either a very high purity metal or thallous sulphate is produced.

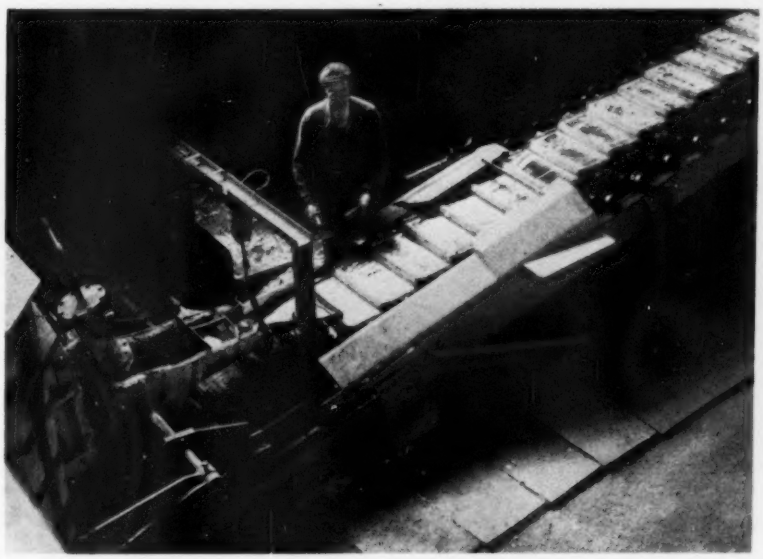
Thermal Zinc

For the production of thermal zinc from the other ores and oxides, chlorinated or not, which the harmful impurities and the lack of secondary metals make less suitable for the electrolytic process, the company has available five foundries: three in Belgium, one in France and one in Germany (Altenberg).

The horizontal retort furnaces, the principle of which was used at the very outset by Vieille-Montagne, have not been abandoned for other more modern thermal processes, in spite of the handicap of batch working and the special skill required from the labour used. In fact, the furnaces, with which the factories are at present fitted, are of large capacity: they reach a production of zinc and marketable zinc dusts of 14 tonnes per day per furnace; in addition, constant improvements have been effected.

In particular, improvements in the retort charging and discharging machines, have made it possible to reduce furnace labour considerably whilst making work less arduous and increasing production and output of zinc.

The use of large external condensers, doing away with the small individual condensers, has increased production and reduced the consumption of fuel by 25 per cent due to the injection into the furnace of the carbon monoxide generated in the retorts. At present, the total consumption of fuel—heating coal + reducing coal—is about 1,000 kg/tonne of zinc.



Automatic casting machine for zinc ingots

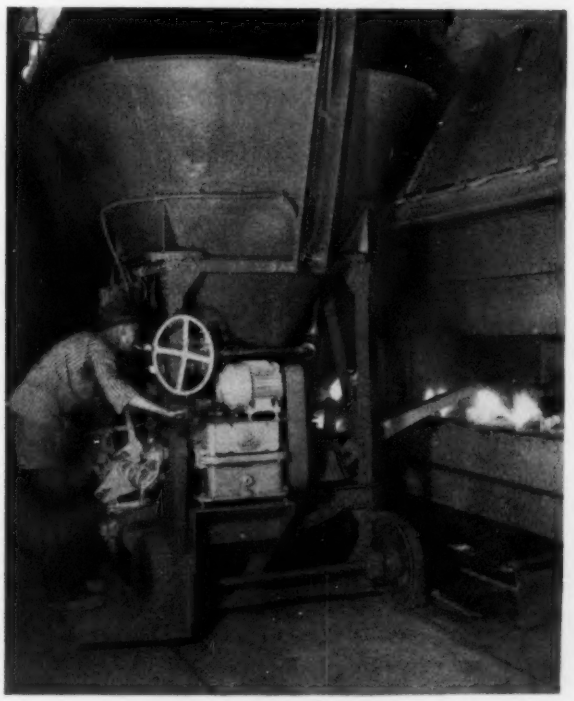
In addition, zinc dusts are produced independently of the furnace and almost all the zinc vapours from the retorts are collected in this form.

Finally, by the use of high quality retorts, a service life of 50 days is now obtained.

Part of the zinc dusts produced in the furnaces is used for electrolysis, as a purification precipitation agent; the lead and cadmium which they contain are recovered there.

Zinc Dusts

Research on the various chemical and physical properties which the zinc dusts should possess has been carried out bearing in mind their various uses: precipitation agent for the purification



Charging machine for zinc furnaces

Zone melting furnaces for the production of germanium

of electrolysis solutions, manufacture of hydrosulphite and pigment in anti-corrosion paints.

This work has made it possible to understand better the characteristics of these dusts and enabled the manufacturing conditions to be controlled according to their end-usage.

Production of Zinc White

Four processes are used, each having its own characteristics both as regards the charge and the quality of zinc produced.

Direct zinc oxide is obtained by reduction of ores having undergone, on roasting in a fluidized bed, a very thorough removal of the lead and cadmium. The roast is mixed with carbon, agglomerated, coked, and treated in a blast furnace of the same type as those at Balen and Viviez.

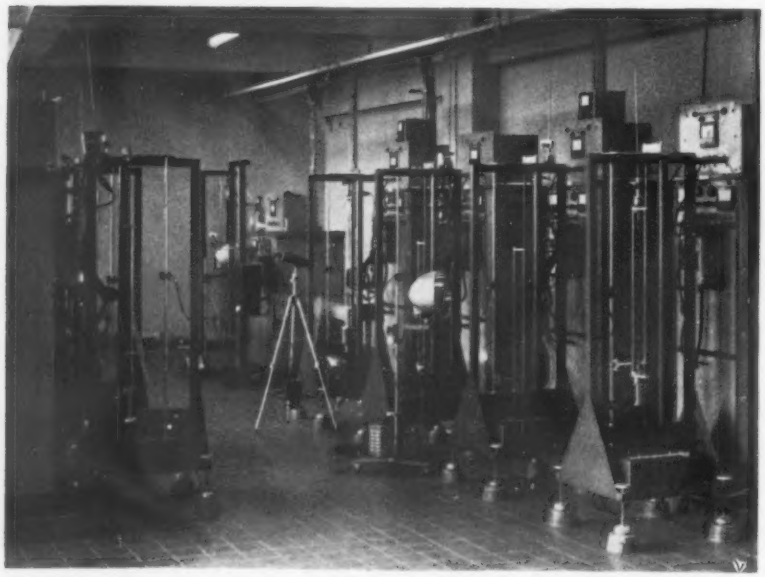
Indirect zinc oxide obtained from very varied metallic, zinciferous materials is produced by three different processes: the "Smelting" process, with rotary furnaces fed with zinc-iron mattes; the "New Jersey Rectification Column" process, using raw thermal zinc, which gives a white of exceptional purity and whiteness; and the "Grillo" process which, in a horizontal retort furnace, makes it possible to obtain a very fine quality white with a very impure charge of zinc-iron mattes or alloy waste.

Worked Zinc and Lead

The company's five rolling mills (one of which is at Altenberg) produce a large tonnage of zinc sheets for roofing and zinc strip. In the various rolling-mills, other allied products have been developed. These include the zinc-copper-aluminium alloys, plates for photo-engraving, zinc wire, zinc-ware roofing products, rounds for manufacturing battery cups, extruded parts, plates for cathodic protection, etc.

The lead produced in the lead factory is partly converted, in an adjacent workshop, into rolled sheets, pipes, traps, solders, wire and bricks for nuclear protection.

Installation for the floating zone production of silicon



Special Products

Before the semi-conducting properties of the metal were known, germanium was regarded as one of the most annoying impurities which simply had to be removed from solutions before they were sent to the electrolysis cells. The special closed loop cycle of the Balen factory described in the foregoing aggravated still more the effect of this impurity which, constantly recycled, enriched the solutions unceasingly, by passing successively into the three elements of the closed circuit: cupola, lead furnace and electrolysis.

The special purification which proved necessary, gave a germanium-bearing concentrate suitable for the subsequent production of metal.

Schematically, this manufacture comprises: extraction of the germanium from the concentrates in the form of $GeCl_4$, purification, hydrolysis and production of GeO_2. This latter is sold as it is or converted into metal by reduction with hydrogen and refining of the metal produced by zone melting.

The experience gained by the laboratories specializing in the production of germanium has naturally led them to undertake research work for the production of silicon of electronic quality, the metallurgy of which shows appreciably the same physico-chemical techniques. La Vieille-Montagne is at present one of the producers of this metal.

La Vieille-Montagne also produces common metals with a degree of purity exceeding the customary commercial standards. These exceptional purities are obtained by special techniques: zone refining, electrolyses or successive redistillations, etc., following the final phase of the manufacture of the industrial base metal. The present manufacturing programme includes zinc 99.9995, lead, cadmium, thallium, bismuth, arsenic and indium with purities of 99.999-99.9999 per cent, and zinc bromide and spectrographically pure thallium iodide and thallium chloride.

Research Organization

Specialized works laboratories, fitted with modern equipment, backed by a central laboratory which, on the general research side, deals with special studies requested by the works, ensure, under the best conditions, efficiency and speed of work.

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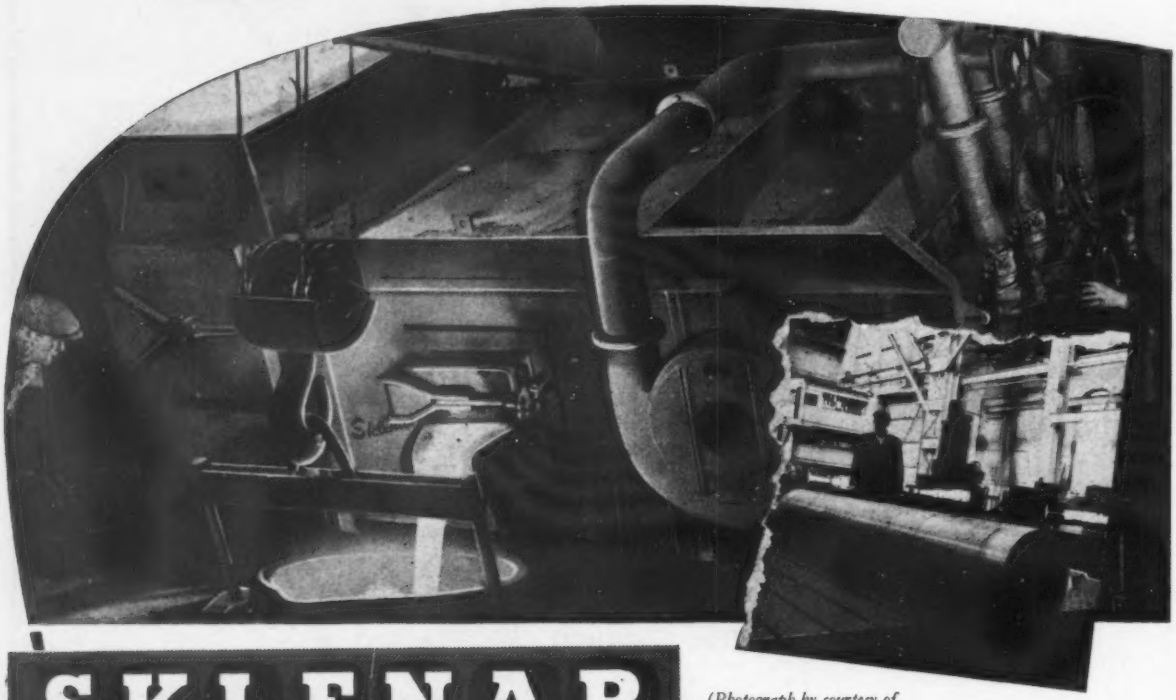

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Works Visits

Société Générale Métallurgique de Hoboken

ONE of the world's largest metallurgical undertakings in the field of non-ferrous metals today, the activities of the Société Générale Métallurgique de Hoboken are concerned with more than 20 different metals as well as their chemical compounds.

Mention must be made, in particular, of the processing of complex ores of copper, lead, tin, cobalt, germanium, uranium, sodium, etc., with recovery of precious metals as well as of such metals as antimony, selenium, bismuth, etc. The chemical compounds of metals produced include the oxides and salts of cobalt, the salts of radium, germanium oxide, oxides of tantalum and niobium, the oxides and salts of uranium, nickel sulphate, sodium sulphate, sulphuric acid, etc.

The company has, at the same time, embarked decisively on the operation of new, specialized metallurgical processes, in which field it has achieved the production of a very extensive range of high-purity and semiconductive elements.

The company possesses three main centres of operations:—

(1) The Hoboken works, which comprises a smelter for lead and copper-lead ores, a lead refinery with a capacity of 75,000 tons of lead per annum and a large installation of converters for the treatment of mattes. It likewise comprises a tin smelter and refining plant, as well as refining plant for precious metals. The main products of these works include pure and alloyed lead, blister copper, which is subsequently refined at the Olen copper refinery, tin, antimony, bismuth (pharmaceutical grade), selenium (commercial and rectifier grades), gold, silver, platinum, palladium, tantalum, niobium, sulphuric acid, and commercial arsenic compounds.

(2) The Olen "Chemical Products" division, with the works of the Union Minière du Haut-Katanga in Africa, is one of the world's largest producers of cobalt, which is made available mainly in the form of various special products, oxides, salts, powder, etc. The works comprises a division for the production of radium, which occupies first place among the world's producers of this material. The same is true of its germanium division, which produces over half the total quantity of germanium used throughout the world.

Here also is situated the plant for the manufacture of nuclear-grade uranium in the form of oxides and salts of the metal. A large works for the manufacture of electronic-grade silicon is at present being completed. The division likewise produces sodium sulphate and nickel sulphate.

(3) The works for the electrolytic refining of copper is also situated at Olen, and a more detailed description of this works follows.

The electrolytic copper refinery of the Société Générale Métallurgique de Hoboken is situated on the south bank of the Meuse-Escaut Canal, halfway between the port of Anvers and the Campine coal basin.

Said to be the largest in Europe, the refinery has a cathode capacity of about 180,000 tons of electro-copper per annum.

In addition to the blister copper produced at the Hoboken works, the refinery processes considerable amounts of raw copper obtained from different sources, in particular the blister copper obtained from the Union Minière du Haut-Katanga, as well as copper turnings and scrap.

Along the bank of the canal the refinery is provided with a quay of nearly 200 metres in length, and equipped with three mobile cranes of 5-ton capacity.

The raw copper delivered to the works is generally in the form of 150 kg ingots. They are stacked on trucks drawn by diesel locomotives to a weighing station, and then to a modern sampling station.

The metal stockyard, which is located at the middle of the works, is served by two overhead cranes and may contain over 40,000 tons of copper.

The series of operations carried out at the Olen electrolytic refinery include (1) melting and refining of the raw copper and the casting of the metal into anodes to be used in the electrolysis; (2) the electrolytic refining of the metal; (3) the fabrication of the cathode copper into commercial products.

Anode Foundry

The works has three furnaces for melting metal for the casting of anodes

Charging raw copper into one of the furnaces at the Olen foundry

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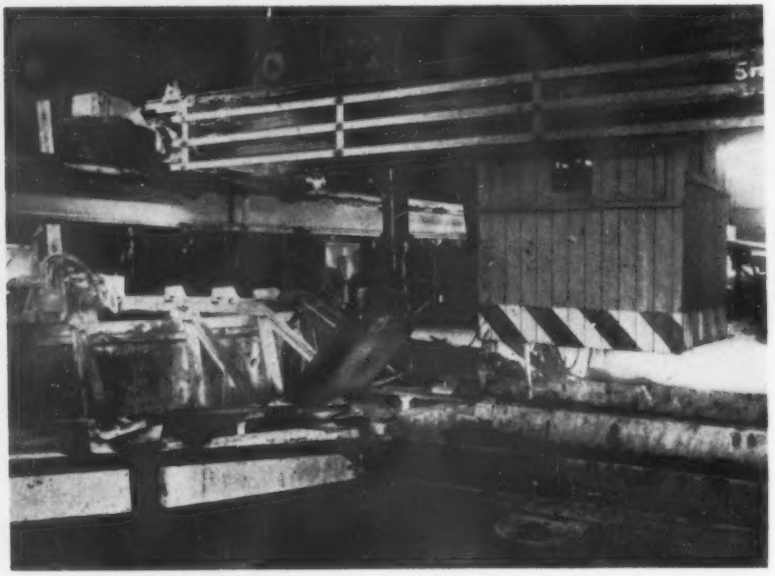


Removing anodes from the moulds

with a capacity of 350 tons and heated by powdered coal. The furnaces have a domed roof of silica bricks, and side walls and bottoms lined with magnesite bricks. The metal is charged into the furnace by means of a charger mounted on an overhead crane.

The fuel supply is turned on fully as soon as charging starts. The charger arm can be introduced into the furnace to deposit a pile of ingots exactly on the required spot.

It takes two-and-a-half hours and a certain amount of skill to charge 350 tons of metal into the furnace. After the metal has been charged, the furnace doors are sealed and the temperature rises progressively to 1,500° C., whereupon melting proceeds with firing at the maximum rate.

The refining of the metal comprises, in fact, two operations: the blowing of the molten metal with compressed air and the skimming of the melt to remove the dross formed by the impurities which have been oxidized and the ash left after the combustion of the coal. Blowing and skimming are continued for 5-6 hr. up to the time when the charge has been completely melted and refined and is at a temperature of 1,170°-1,180° C.

If necessary, a refining treatment with soda is carried out to reduce the arsenic content of the metal.

During the blowing of the metal, oxidation of the impurities contained in the copper, in particular the sulphur, necessitates a certain oxidation of the metal. Poling, which involves the plunging into the molten metal of freshly cut wood poles, has the effect of reducing the copper oxide content to normal.

Anode Casting

The melt is covered with coke and the metal is cast into anodes, which are plates measuring 35½ in. square by 1½ in. in thickness, and provided with two lugs by means of which they are suspended in the electrolytic cells. These anodes weigh 600 lb. each.

Casting is effected by means of three Walker-type casting machines, one for each furnace. These machines are of the roundabout type, with twenty-one moulds, brought successively into position for casting, which takes place at the rate of 45 to 50 tons/hr. of metal.

Process inspection in the electrolytic copper refinery

The moulds themselves are of copper and are manufactured in the works. Deterioration of the mould surfaces is prevented by coating them before each filling with a suspension of powdered silica.

Casting of the metal starts with the removal of the upper portion of the plug of refractory mix, by means of which the casting port is closed. The molten metal is carried to the pouring ladle along a channel. The ladle is remotely-controlled and fills the moulds as they present themselves one after the other in front of the pouring lip.

The cast anodes, while still hot, in spite of abundant spraying with water, are removed from the moulds and plunged into cooling troughs. From these they are removed by an overhead crane which deposits them, 35 at a time, on trucks which carry them to the electrolysis building, passing on their way inspection and deburring stations.

A typical analysis of the anode metal is: copper 99 per cent, silver 40-60 oz/ton, gold, 0·05-0·3 oz/ton, arsenic 0·13 per cent, antimony 0·02 per cent, lead 0·2 per cent, and nickel 0·1 per cent.

Casting wirebars in the Walker-type rotary casting machine

Electrolysis

The electrolysis building covers an area of approximately 1½ hectares (3¾ acres). In the four bays, each 20 m. wide, are arranged the 1,410 electrolytic cells, with walls constructed of reinforced concrete lined on the inside with antimonial lead.

The anodes are arranged in parallel in groups of 35 in the cells, where they are connected electrically in series.

The anodes and cathodes which are suspended in the cells (35 anodes to 36 cathodes) are spaced at 3⅞ in. between centres. The electrolytic process results in the dissolution of copper from the anode and its deposition on the cathode. Some of the impurities present in the anode (arsenic, nickel, cobalt) go into solution, while others, in particular the precious metals, lead and selenium, remain insoluble and settle on the bottom of the cell in the form of a sludge. This sludge is removed each time the anodes are replaced. It is freed from copper by lixiviation and dried, and is sent to the Hoboken works for the recovery from it of lead, selenium and precious metals. The impurities which dissolve are maintained below a predetermined maximum concentration by a continual withdrawal and treatment of the solution.

The arsenic, which is deposited electrolytically, is also sent for processing to the Hoboken works. The salts of cobalt and nickel which are recovered by evaporating the residual solutions are sent to the neighbouring Chemical Products Division.

By this continuous treatment, the composition of the electrolyte is maintained at approximately 43 gm/L. copper, 210 gm/L. free sulphuric acid, 10 gm/L. (max.) arsenic, and 10-15 gm/L. nickel.

The life of an anode is 28 days and that of the cathode 14 days. The cathodes are thus replaced half-way through the life of the anodes. The cathode starting sheets are produced in a special electrolytic section. They are made by detaching a thin deposit formed in the course of 24 hr. on cathode starting blanks of rolled copper.

After flattening, these deposits, which have a thickness of about 0·03 in. and weigh approximately 13·2 lb., are provided with suspension lugs and introduced as starting sheets into the electrolysis cells.

During the time they are in the cells the cathodes are kept under careful observation and are controlled by a team of inspectors, who correct any short circuits, straighten out any cathodes which become distorted, check the contacts between the electrodes and the current busbars, and remove any nodules or trees which may form on the surface of the cathodes. By taking all these precautions it is possible to achieve a current efficiency exceeding 97 per cent even with a current of 13,000 amp., which corresponds to a current density of 17·33 amp/ft^2.

After 14 days in the cells, the cathodes are withdrawn and thoroughly washed. They weigh about 250 lb. and are sent to the foundry for conversion into commercial products.

Commercial Products

Copper cathodes have to be remelted in order to cast the metal into shapes required for subsequent fabrication: wire bars (bars for rolling and drawing), cakes (for rolling), ingots for the manufacture of alloys (bronze, brass, etc.), billets (for the manufacture of tubes, etc.).

The foundry is equipped with three large furnaces having capacities of between 320 and 380 tons. Each furnace is provided with a waste-heat boiler in which more than 50 per cent of the heat used to heat the furnaces is recovered. The steam from these boilers is supplied to the electric power station and contributes to the generation of current required for the electrolysis.

Like the anode furnaces, the foundry furnaces have a roof of silica bricks and walls of basic bricks. The furnace bottoms, on the other hand, are of silica bricks.

Each furnace is provided, like the anode-casting furnaces, with a Walker-type rotary casting machine on which the moulds are carried into position below the casting nozzle.

A charger loads the furnaces with stacks of cathodes of 2½ tons at a time. Melting takes from 10 to 12 hr. This is followed by a period of oxidation during which air is blown through the molten copper to effect oxidation of the impurities still present in the metal, which are then removed as dross by skimming from time to time.

After the oxygen content of the copper has reached a value of about 0·85 per cent, the melt is covered with wood charcoal and is then poled.

When the required degree of deoxidation of the copper has been reached the metal is cast. The moulds, which are carried on a circular casting machine and coated with a suspension of bone ash, are filled in succession with molten metal. As soon as the metal has solidified, the moulds are automatically tipped and the ingots drop out into a tank filled with water,

where they are cooled and acquire their characteristic red colour. A conveyor extracts the ingots from the tank and carries them to the inspection bay.

The complete process, comprising the melting, refining and casting operations is completed in 24 hr. The ingots obtained have a typical analysis of 99·96 per cent copper, 0·031 per cent oxygen, 0·0008 per cent sulphur, 0·0012 per cent lead, 0·0008 per cent arsenic, 0·0011 per cent nickel, and 0·0012 per cent silver.

Vertical Casting

In order to meet the requirements of fabricators, the Société Générale Métallurgique de Hoboken has developed a plant for the vertical casting of copper which permits the production of, in particular, billets and plates of electrolytic copper and phosphorus-deoxidized copper.

The process comprises three stages. In the first stage, the cathodes are mechanically charged into three oil-fired rotary furnaces in which they are melted and refined. The molten metal is then transferred to an electric induction furnace capable of holding 10 tons of molten copper. In this furnace the metal is very rapidly deoxidized. The molten metal is then cast into billets or plates, using a rotary casting machine provided with vertical water-cooled copper moulds. The billets and plates are ejected from the moulds into a water trough for final cooling and are subsequently removed from the trough by a conveyor, which carries them to an inspection bay.

Large sizes of electrolytic copper slabs are cast in a special installation.

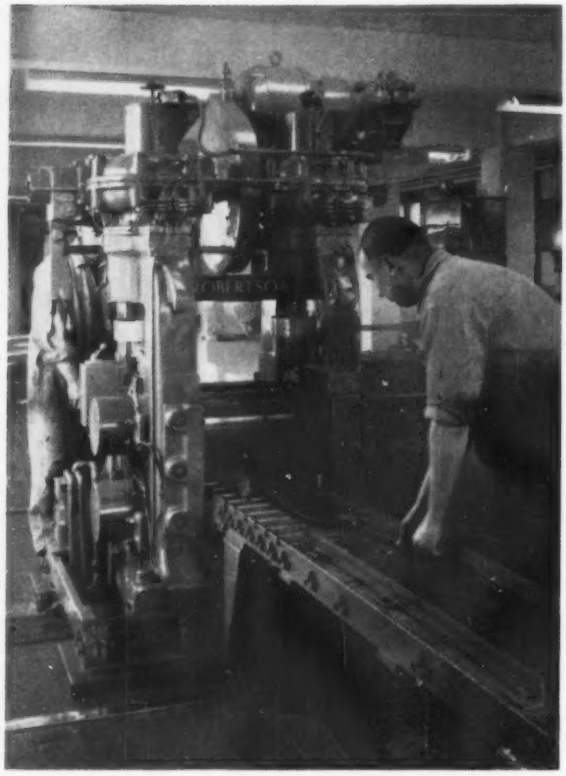
All the cast products produced at the Olen electrolytic refinery undergo a careful and detailed inspection.

To special order, billets and slabs are given special finishing treatments, such as, for example, the removal of the casting skin formed on the surface during solidification.

The range of products supplied includes 185 different shapes and grades.

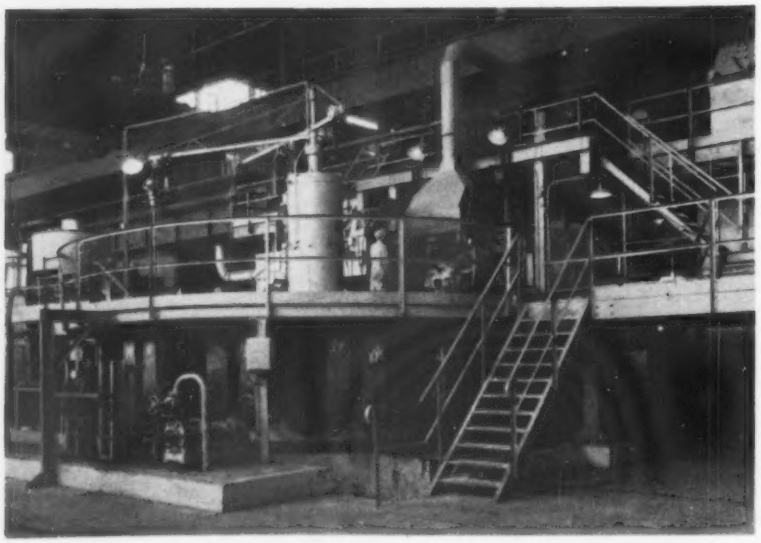
Like any other large industrial plant, the Olen electrolytic refinery incorporates various auxiliary shops and installations essential to its activities. There is a central power station, as well as stores, mechanical and electrical maintenance shops, a sheet metal working shop, a forge, building, woodworking and other shops.

Welfare services include canteens, cloakrooms, washing facilities, showers and a laundry. A special safety shop undertakes the cleaning, checking and repair of equipment such as masks, goggles, special clothing, footwear, etc., before these are issued to workmen who need them.



Robertson 2-high cold mill for rolling cakes in the physical testing laboratory

Vertical billet casting machine for electrolytic and phosphorus-deoxidized copper



Laboratories

Large laboratories for both research and routine control are housed in a separate building and provided with extensive modern equipment. They include chemical, physico-chemical, spectrographic, physical testing and metallographic sections.

The metallographic examination is supplemented by X-ray investigation of the crystal structure of the metal.

In the course of this work an enormous collection of metallographic specimens has been formed, with thousands of specimens representing all the stages of processing of the metal. This collection constitutes a valuable source of information on different metallographic aspects which may be encountered in wrought copper, and provides evidence of more than 30 years' active and dependable collaboration between the Olen electrolytic refinery and the copper fabricating industry of Western Europe.

Works Visits

Société Anonyme Phenix Works

ORIGINATING in Liége in 1881 in a works for galvanizing sheet, the Société Anonyme Phenix was transferred in 1905 to Flemalle-Haute, 13 kilometres from Liége on the banks of the Meuse. In 1910, the company joined a similar undertaking situated at Roux near Charleroi, the new company being given the name Société Anonyme Phenix Works. At that time, the activities of the company were still limited to the galvanizing of thin sheet.

Between the two world wars, the company extended its interests into the galvanizing of household utensils, the manufacture of lead-coated sheet, the hot-rolling of thin sheet and the production of hot-dip tinplate.

More recent technical developments brought important modifications to the production facilities.

Overhead transporters link the works directly with the Meuse and permit the daily handling of 2,000 tons of products. Between 25,000 and 30,000 tons of finished products monthly are supplied to all countries of the world.

The works provide employment for some 2,300 persons, with a staff of 370.

For future extensions the company has a large site on the right bank of the Meuse of which a small portion is already occupied by a new aluminium works, planned to open in 1962.

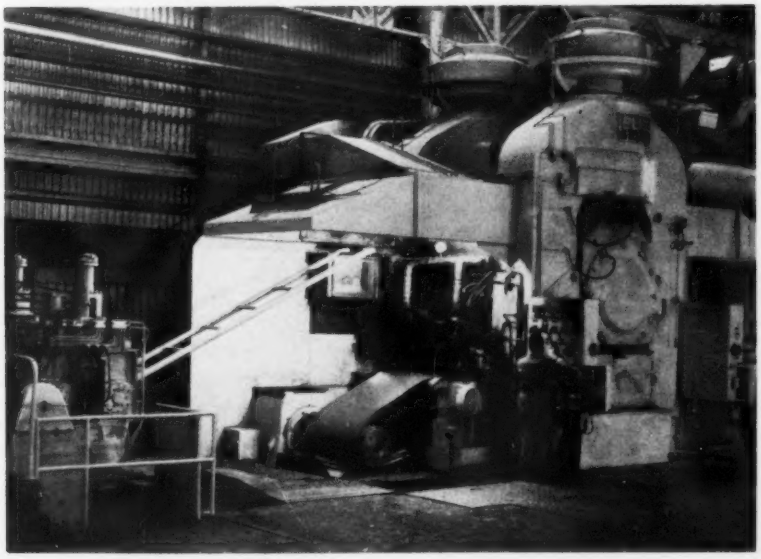
Rolling Mills

The equipment for the hot rolling of thin sheet is installed in five shops parallel with and joined to each other, having a length of 150 m. and a width of about 25 m.

The heating of the blooms and plates is carried out in two Wean mechanical double-chamber furnaces heated by town gas.

The rolling mills are arranged in two groups. In the first group there are three two-high stands arranged in line.

Bliss 4-high reversible cold rolling mill



The bottom rolls are driven by a single 2,300 h.p. motor. One stand, completely mechanized, serves for finishing; the other two stands are for rolling down and are hand-operated.

The second group comprises five stands (four two-high and one three-high mill) also arranged in line and driven by a single 2,300 h.p. motor, and one two-high mill arranged in tandem with the three-high mill and driven by a 500 h.p. motor.

The three-high mill serves for rough rolling and is entirely mechanized. The bottom roll is driven by the 2,300 h.p. motor, the middle roll is an idler roll and the top roll is driven by an auxiliary 40 h.p. motor.

Two of the two-high stands are for rough rolling and are partially mechanized. The two-high tandem mill is fully mechanized and operates either as an intermediate or finishing mill; the final two-high mill is fully mechanized and serves for finish rolling.

All the two-high mills are fitted with chill-cast iron rolls of 800 mm. or 850 mm. diameter and of 1,080 mm. to 1,200 mm. or 1,500 mm. width. The three-high mill is fitted with two large rolls of 800 mm. diameter, of steel, and a middle roll of 500 mm., also of steel, the width of the rolls being 55 in.

Annealing—This is carried out in six Heurtey rectangular bell-type furnaces fired with light fuel oil. Twenty-seven furnace bases are available. In general, the annealing does not require the use of protective gas. Where necessary, a protective gas, consisting of a mixture of nitrogen and hydrogen, is available.

Cold Rolling Thin Sheet—For this purpose, four shops are equipped, having a length of 250 m. and widths ranging from 18 m. to 22 m. These shops house a store for the coils of hot rolled strip, a pickling line and a cold rolling mill, the degreasing line and the skin pass mill, a shear for the tinplate, two cold rolling mills, another skin pass mill and shear, a shear and slitting line for coils, and lines for the sorting, marking, packing and storage of cold rolled sheet.

Pickling — A hydrochloric acid pickling line was adopted for two main reasons, namely, the better appearance of the pickled strip and the possibility of neutralizing the spent pickling liquor in plant which was already available in connection with the galvanizing.

The pickling is carried out in a continuous manner in a conventional type of plant. Originally, this comprised three vats of 25 m. length. A fourth vat has recently been added permitting an increase in output of about 25 per cent. The maximum speed along the line is 50 m/min.

With a view to reducing the pickling costs, and also in order to comply with the increasingly more stringent requirements regarding the disposal of industrial effluents into the river, the company has recently acquired a plant for the regeneration of the hydrochloric acid using the Ruthner process.

The installation is provided in duplicate. Each unit has a regenerating

TABLE I—4-HIGH COLD ROLLING MILLS

	4-high mill I	4-high mill II
Main motor	5,000 h.p.	6,500 h.p.
Screw-down motor	150 h.p.	150 h.p.
Mill motor	3,000 h.p.	3,000 h.p.
Coiler motors	2 × 500 h.p.	2 × 600 h.p.
First pass by	pay-off	coil-box
Maximum speed	9 m/min	10 m/min
Maximum tension	11 tonnes	13 tonnes
Maximum width of strip	1,070 mm	1,100 mm
Rolls		
Back up	48 in. wide	
Maximum diameter	53 in.	
Work rolls	48 in. wide	
Maximum diameter	15·8 in.	

TABLE II—SENDZIMIR MILL

Type	ZR—22—50
Rolls	6 2nd interm. (173 mm. diam.)
	4 1st interm. (102 mm. diam.)
	2 work rolls (54 mm. diam.)
Main motor	6,500 h.p.
Mill motors	2 × 1,750 h.p.
Coiler motors	2 × 750 h.p. + 1 × 750 h.p.
Maximum speed at maximum torque	260 m/min.
Maximum speed at reduced torque	520 m/min.
Maximum tension at 520 m/min.	19·5 tonnes
Maximum tension at 260 m/min.	30 tonnes

capacity corresponding to the pickling of 11,000 tons of steel per month.

Cold Rolling Mills—At present, the company has two reversible cold rolling lines, a four-high Bliss mill (Table I) and a Sendzimir mill, which will be put into operation in October 1961 (Table II).

The rolling lubricant is an aqueous emulsion of palm oil.

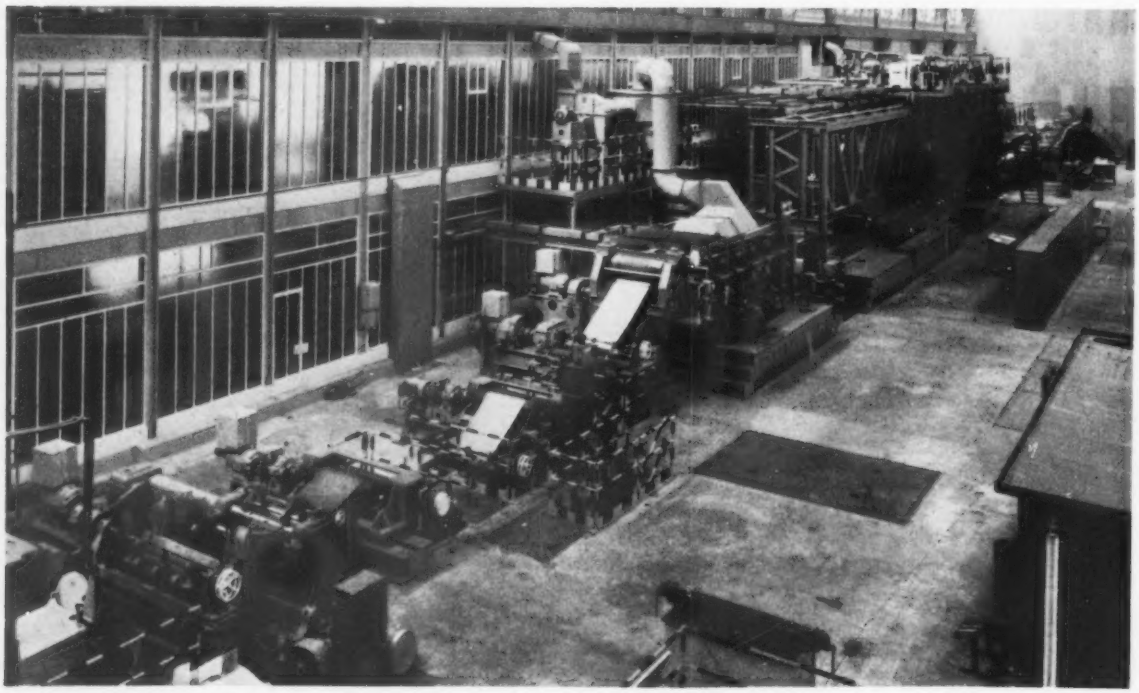
The degreasing line comprises two horizontal vats each 12 m. long. The second vat is provided for electrolytic degreasing with a supply of 3,000 amp. at 12 V, derived from a 5,000 amp. 12 V generator. The maximum speed of the material along the degreasing line is 400 m/min., the maximum width of strip is 1,100 mm. and the degreasing agent is sodium orthosilicate.

Only the coils for tinplate, black plate, sheets for galvanizing by the hot-dip coating (old process), and sheet for the "skin plate" are annealed in the bell-type furnaces. Coils for continuous galvanizing are supplied as-rolled.

The annealing plant comprises nine Wilson-Heurtey bell-type furnaces, three of which have a diameter of 53 in. (capacity 33 tons) with ten bases, and six a diameter of 63 in. (capacity 37 tons) with seventeen bases. Each furnace is equipped with eight burners each consuming 15 L/hr. and is fired with fuel oil having a density of 0·850.

Temper Rolling — Except for coils for continuous galvanizing, all cold rolled material is subjected to temper rolling on one of the two skin pass mills of the Blain type in which the material is subjected to a certain elongation. The mill comprises essentially two groups of five stretcher rolls which are mechanically inter-linked, and a four-high stand. The peripheral speed of the rolls at the exit end is higher than the speed of the rolls at the input end by an amount proportional to the elongation to which it is intended to subject the strip. The elongation is localized in the region which, at any given time, is being compressed by the rolls of the four-high stand, the pressure

General view of the Ferrostan electrolytic tinning line



exerted by which is controlled hydraulically. The amount of cold working imposed by the rolls of the four-high stand and by the tension exerted by the stretcher rolls can be readily controlled according to requirements. An increase in the pressure exerted by the rolls of the four-high stand effects a corresponding reduction in the tensile strain and vice versa.

This type of mill is particularly suited to the processing of thin strip. Its design is very simple: a single motor drives all the working rolls. The stretcher rolls are driven by the movement of the strip; no electrical control is required.

The ratio of the entry and exit speeds is controlled without difficulty by replacing one of the gear wheels connecting the stretcher rolls by another one with a different number of teeth.

The company has two mills of the above type, which it has supplemented by providing a two-high stand in front of the skin pass I and a four-high stand in front of the skin pass II mill. Experience has shown that a very small degree of cold working (less than 0·5 per cent) given before the entry of the strip into the skin pass mill can suppress the tendency to develop edge cracks. These stands in front of the skin pass mills are not driven, the rolls being turned by the passage of the strip.

The main characteristics of the skin pass mills are shown in Table III.

Each of these mills is followed by a Hallden shear (maximum speed 100 m/min.). The second mill is, moreover, provided with a coiler and a pay-off reel in front of the shear.

TABLE III—SKIN PASS MILLS

	Skin pass I	Skin pass II
1st stand	*2-high*	*4-high*
Diameter of back-up rolls	—	600 mm.
Width of back-up rolls	—	1,190 mm.
Diameter of work rolls	600 mm.	325 mm.
Width of work rolls	1,295 mm.	1,190 mm.
2nd stand	*4-high*	*4-high*
Diameter of back-up rolls	600 mm.	600 mm.
Width of back-up rolls	1,190 mm.	1,190 mm.
Diameter of work rolls	325 mm.	325 mm.
Width of work rolls	1,190 mm.	1,190 mm.
Motor	200 h.p.	360 h.p.
Maximum speed	140 m/min.	170 m/min.

TABLE IV—CONTINUOUS GALVANIZING LINES

	I	II
Nominal capacity	7 tonnes/hr.	10 tonnes/hr.
Maximum width of the strip	1,100 mm.	1,100 mm.
Strip thickness	0·20—1·25 mm.	0·20—1·25 mm.
Maximum speed	66 m/min.	80 m/min.
Degreasing	chemical	electrolytic
Heating by radiant tubes (town gas)	103 tubes	125 tubes
Cooling controlled by electrical resistance units (48 kW per unit)	36 units	42 units
Air cooling in furnace	—	10,000 m³/hr.
Air cooling beyond furnace	40,000 m³/hr.	70,000 m³/hr.
Electrical heating of tank	186 kW	186 kW
Capacity of tank Zinc	42 tonnes	42 tonnes
Lead	10 tonnes	10 tonnes
Capacity of strip accumulators		
Entry side	65 m.	130 m.
Exit side	40 m.	44 m.
Ammonia crackers	5 of 7·5 m³/hr.	2 of 30 m³/hr.

Tinplate Lines

Equipment for hot-dip tinplating comprises five machines of which three have a width of 75 in. and two of 64 in. The pickling and tinplating take place along two parallel lines, whereas the degreasing, the drying and sorting are carried out in a single line.

An electrolytic pickling in hydrochloric acid precedes the tinplating. On leaving the tin bath the sheets are degreased in a hot solution of Sulfocor and are then dried by means of bran. The bath is heated by town's gas with immersion type burners.

At the maximum speed of the machines (10 m/min.), the overall output attains about 4,000 tons/month.

Electrolytic Tinplating—A Ferrostan plant was put in service by the company in August 1961. The main characteristics of the plant are: maximum speed, 1,200 ft/min.; degreasing section, 1 vat, 8,000 amp.; pickling section, 2 vats, 1,600 amp.; tinplating section, 5 vats, 64,000 amp. (it is possible to add five further vats) (64,000 amp.); chemical treatment section, 1 vat, 4,500 amp. (it is possible to add one further vat); melting by resistance heating, power 3,000 kVA.

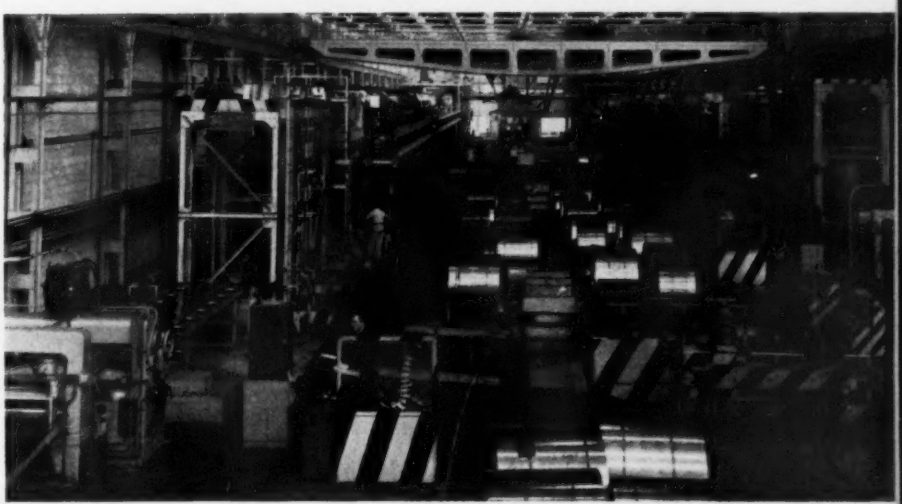
The line incorporates an edge trimmer. Space has been left for the installation of two reels, which would provide the possibility of supplying coiled tinplated strip.

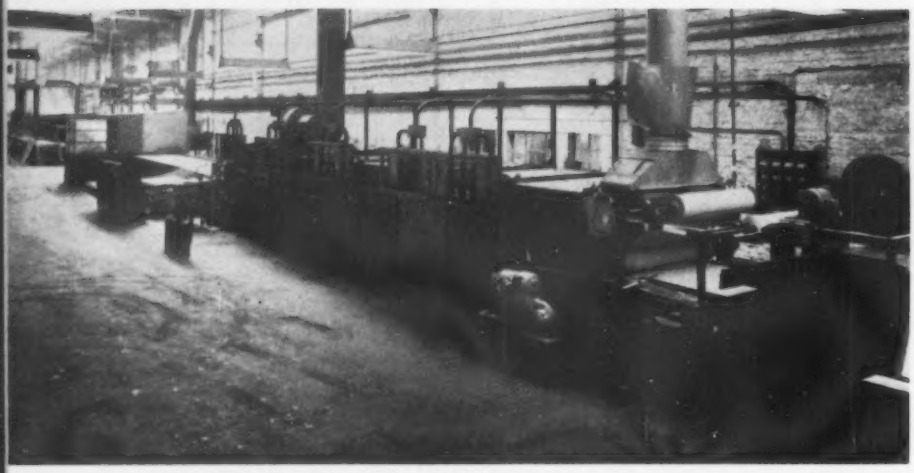
The rectifiers of the power supply are of the germanium type.

The thickness of the strip which is treated ranges from 0·15 to 0·60 mm., the width from 456 to 1,016 mm., the length of cut by means of the rotary Hallden shear may be varied from 456 to 1,060 mm., and the thickness of the tincoating ranges from 0·25 to 1 lb. per basis box (differential coating thickness, 1 lb. to 0·25 lb. per basis box).

The line will go into service in two stages: the present stage is characterized by a speed of 750 ft/min., the use of five tinplating vats with a current

General view of the two Armco-Sendzimir continuous galvanizing lines





Line for plastics-coating of steel or aluminium sheet

of 64,000 amp. and of one chemical treatment vat, and the second stage by a speed of 1,200 ft/min., the use of ten tinplating vats with a total current of 128,000 amp., of two chemical treatment vats and two coilers.

Galvanizing Lines

The galvanizing shops comprise a section for the continuous galvanizing of strip, a section for the galvanizing of thin sheet by the wet process, a section for the continuous galvanizing of small sheets and a section for the galvanizing of household utensils.

Continuous Galvanizing — Two Armco-Sendzimir lines with a Heurtey annealing furnace occupy a single building measuring 150 m. by 20 m. These lines differ from the American and English Armco installations in the design of the annealing furnace through which the strip passes in a hairpin shaped loop. This arrangement enables an important saving in heat consumption as a result of the heat exchange which occurs between the hot strip leaving the furnace and the cold strip entering the preheating furnace. It is estimated that saving in gas consumption of about 40 per cent is achieved.

Principal characteristics of the galvanizing lines include those shown in Table IV.

Each line is provided with a Hallden shear and a coiler.

A third line, having a nominal capacity of 18-20 tonnes/hr., is at present under construction and will be put into operation towards the end of 1962. The general arrangement of this line is the same as that of the existing lines except for the maximum speed, which will be in excess of 100 m/min., and the width of the strip, which will be increased to 1,250 mm. instead of the 1,100 mm. of the existing lines.

Thin Hot and Cold Rolled Sheet Galvanizing—Prior to 1956, when the first galvanizing line was put into operation, the shop comprised nine galvanizing tanks using the wet process. Following the introduction of the continuous galvanizing process, five of these tanks were put out of use and two others will likewise suspend operations within the next few months.

The two tanks remaining in service have the following characteristics: pickling in hydrochloric acid and manual rinsing; three immersed rollers of 200 mm. diameter; maximum width of sheets, 1,250 mm.; monthly output, 1,500 to 1,800 tonnes/tank.

Galvanizing of Thin Strip — This operation is carried out in a continuous manner on a line comprising: two strip feeders (13 reels); a welding machine; a loop pit; a hydrochloric acid pickling vat; two intermediate coilers; two coilers for reels; maximum speed, 3·5 m/min.; capacity 500 tonnes/month.

Galvanizing of Household Utensils— There are two tanks, each having a capacity of 48 tonnes of zinc, which are used for galvanizing household utensils, and also large sheets measuring up to 1,250 by 5,000 mm. and up to 5 mm. thickness.

After hydrochloric acid pickling, rinsing and fluxing, the articles are suspended from a continuous chain on which they are carried through a drying oven heated by means of radiant panels.

All the spent pickling solutions arising from the above installations are neutralized with lime before being run into the river. The ferrous hydroxide mixed with calcium chloride is washed and oxidized to ferric hydroxide, which is used as a material for removing hydrogen sulphide from coke-oven gas.

Various machines are available for the manufacture of different types of corrugated and ribbed sheet used in building. The corrugating shop is provided with a dozen press brakes, a double roller American-type corrugating machine, a modern Eichener double roller machine and another continuous Eichener machine.

"Skinplate"

In 1955, the company decided to extend its activities into the manufacture of plastics-coated sheet.

It was decided not to undertake any original research on methods of bonding the plastics film to the sheet and, instead, a licence was acquired from the United States Rubber Company for the Marvibond process which already had achieved a remarkable success in America.

The plastics-coated sheet, with a maximum width of 1,250 mm., manufactured by the Phenix Works is known under the trade name of "Skinplate". The material is manufactured on a production line comprising the following units:

A section for the preparation of the steel or aluminium sheet by degreasing, phosphating, rinsing and drying and a section in which the plastics film is applied. In this section, the sheet is roller-coated with adhesive, passed through an electric radiant-tube-heated furnace and then between rollers which apply the film to one or two sides of the sheet, and, finally, through an air dryer. The speed of the material along the line attains 9 m/min.

The whole line has been designed to permit the processing of continuous strip, being provided with a pay-off reel on the entry side and a shear and a coiler on the exit end.

Workshops and Laboratories

A very large engineering shop, a sheet metal working shop and an electrical engineering shop, and chemical and mechanical testing laboratories, complete the facilities available on the site.

As regards the laboratories, they are equipped with everything that is necessary for the routine control of the raw and manufactured products.

Research is being carried out on improvements and possible future developments of manufacturing processes.

Future Prospects

All the activities of the Phenix works are based on the rolling and surface treatment of flat steel products. Undoubtedly, the continuing expansion of the markets for thin sheet, galvanized sheet, tinplate and plastics-coated sheet will lead the company to increase its productive capacity for these products.

As a result of the demand for foil in packaging, it was decided in 1960 to build a new works on the Yvoz-Ramet site for the rolling and fabricating of thin aluminium sheet.

At the start (at the beginning of 1962), the new works will be equipped with two four-high mills for aluminium, and auxiliary plant such as annealing furnaces, shears, etc., as well as processing equipment such as varnish-coating machines, machinery for printing on aluminium by different methods, corrugating machinery, etc. The initial capacity of 150-200 tonnes/month will be raised in the course of the following years to 300 and then to 600 tonnes/month.

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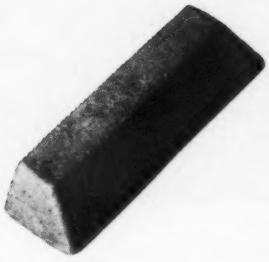

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GATEWAY TO QUALITY

Industrial News *Home and Overseas*

American Visitors

Ten members of the National Screw Machine Products Association, U.S.A., recently paid a visit to the Sunbury factory of **Cold Forging Ltd.**, one of the International Cold Forging group of companies. The visitors had been touring Europe for several weeks studying production methods in various countries.

The Americans were clearly impressed by the "Colforg" equipment, and admitted that it was more highly developed than anything they had seen hitherto. They were particularly interested in a "Colforg" P 302 press fitted with a four-stage rotary indexing tool producing pierced, indented billets at the rate of 2,700/hr. A similar press was seen recently at the European Machine Tool Exhibition in Brussels, producing hexagonal nuts.

The visitors were also shown a film dealing with "Colforg" equipment, after which a lively discussion took place. It was clear that several of the American companies represented had experimented with cold forging for some time.

New Technique

An advance from the metal-to-metal lock-joint of spiral conduit is stated to have been made. **Metal Sections Limited** have devised a new technique of incorporating a rubber mastic sealing compound into the lock-joint as it is being formed.

It is claimed that the sealing compound — 3 M's EC750C — provides an air-tight tube, preserves the lock-joint from rough treatment during transit and on site, and allows for expansion and contraction of the joint caused by temperature variations within an air-conditioning system.

The company states that they have successfully carried out leakage tests on the new tube up to a static internal pressure of 15 lb/in^2, and that their "Helitube" is being marketed with this leak-proof assurance. The modification is now being incorporated in all "Metsec Helitube", which is available from 3½ in. up to 24 in. diameter, and in three different gauges: 25 S.W.G. (0·020 in.), 22 S.W.G. (0·028 in.), and 20 S.W.G. (0·036 in.) in any suitable ductile metal.

New Orders

Orders for Efco furnaces to a value of approximately £70,000 have recently been obtained by **Efco (South Africa) (Pty.) Ltd.** The orders cover an electrically heated closed-quench furnace, a pit type gas carburizing furnace, a continuous mesh belt conveyor furnace and two bogie hearth furnaces each rated at 750 kW. The bogie hearth furnaces are to be supplied to South African Railways for normalizing, annealing and stress relieving steel castings. They will take loads up to eight tons.

Quick Calculations

Said to be invaluable for obtaining adequate information for production and process control, planning, loading and machine efficiency, the "Spencer-Taylor" calculator is being distributed by **Gill Brothers and Partners Ltd.**

No knowledge of mathematical formulae is stated to be needed to find a quick solution on this calculator, and even a junior clerical assistant needs the minimum of practice to solve problems in a few seconds. This precision instrument has been specially designed for industries producing metal or plastics material in the form of rods, wire, strip, bars, tubes, etc., by the rolling, drawing or extrusion processes.

A Bristol Annual Function

On Friday next (October 13), the Bristol and South-West branch of the **Institute of Metal Finishing** will hold its annual dinner and dance at the Royal Hotel, College Green, Bristol, commencing at 7 p.m.

Tickets are 27s. 6d. each, and may be obtained from Mr. R. A. Wilding, 11 Fenton Road, Bristol, 7.

Automation Order

Orders for process control instrumentation totalling £250,000 have been received by **Honeywell Controls Ltd.** for use at the new integrated Spencer steelworks of Richard Thomas and Baldwins Ltd. Much of the installation will be done by Honeywell.

Temperature, flow, pressure and oxygen analysing equipment will be supplied for reheating and heat-treatment furnaces being installed by **Priest Furnaces Ltd., Stein and Atkinson Ltd.** and **Incandescent Heat Co. Ltd.** Instrumentation is also being installed by Honeywell for lime kilns, ore dryers, pickle line, acid recovery and other plant mainly on direct order from R.T.B.

Australian-American Aluminium Project

It is reported that three Australian mining companies have announced plans to subscribe A£7,875,000 to extend their interests in a A£44,000,000 Australian-American bauxite aluminium project. The companies—Western Mining Corporation Limited, Broken Hill South Limited and North Broken Hill Limited—are partnering the Aluminum Company of America in what is claimed to be one of the biggest mining ventures ever undertaken in Australia.

To raise the money, the three Australian companies—known as the Collins House Group—will each make large new issues of shares to their shareholders. The issues will raise about A£6,600,000, the balance being taken from internal resources.

The operating company for the project —Alcoa of Australia Limited—will build an aluminium works at Point Henry, about 50 miles from Melbourne, using bauxite from the Darling range in Western Australia and cheap power from brown coal.

The American company will have 51 per cent of the ultimate A£25,000,000 paid-up capital of Alcoa of Australia Limited. Biggest Australian shareholder will be Western Mining Corporation, with five million shares of 20 per cent of the paid-up capital. Broken Hill South will hold 4·15 million shares and North Broken Hill three million.

Aluminium Foil

A new hard aluminium foil—N.S.4—in thicknesses down to 0·025 mm., is being rolled for the first time in this country by **Venesta Foils Limited.** This new foil differs from commercial purity aluminium in containing 1·8-2·7 per cent magnesium and up to 0·5 per cent each of manganese and chromium.

It is said that the demand for this tougher and stiffer foil comes from industries as widely apart as the aircraft industry, where it is used as the honeycomb centre of flooring, to the display industry for the manufacture of collapsible foil Christmas trees. In this hard temper, and in 0·06 mm. thickness, N.S.4 has a tensile strength of 16-18 tons/in^2.

Licence Agreement

It is understood that **Birwelco Limited** has made an exclusive agreement with Yuba Consolidated Industries Inc., of Tulsa, Oklahoma, to manufacture and sell Aimco Transaire air-cooled heat exchangers in Europe and the British Commonwealth. Birwelco has already received several large contracts for this type of equipment from both the oil and chemical industries.

Transaire air-cooled heat exchangers incorporate finned tubes and electrically driven fans, and are designed specifically for the oil refining, petrochemicals and chemical processing industries. They are particularly useful in areas where the water supply is inadequate or unreliable. The tubes and the fins, which are wound spirally on the tubes, without brazing or welding, by a special mechanical process, can be of mild steel, stainless steel, brass, copper or aluminium, according to the ambient atmosphere and the type of liquid to be cooled.

New Spray Unit

An addition to their range of Graco Hydra-Spray units has recently been introduced by **Alfred Bullows and Sons Ltd.** The new unit (Catalogue No. 226-153), is a 5-gal. version of the Hydra-Spray, which, in common with the other units in this range, operates on the principle of paint under high hydrostatic pressure.

Designed for use with one spray gun, and with economical operation in mind, this unit operates direct from original 1 gal. to 5 gal. open top paint containers. It is very light in weight and can be carried almost anywhere by one man.

The unit is supplied complete with a 23 : 1 ratio Monark pump; air-driven agitator; 5 gal. pail and cover; blow gun for cleaning out tip of spray gun; Graco "Golden" hand spray gun with tungsten carbide spray tip and special hose swivel which gives operator more freedom of movement with less fatigue; 20 ft. length of fluid hose, and built-in foot valve screen. Delivery is ex stock.

Derbyshire Magnesium Plant

It is reported that Magnesium Elektron Limited have appointed the Power-Gas Corporation Limited, of Stockton-on-Tees, a member of the Davy-Ashmore Group, to be main contractors for the engineering of a new plant to produce 5,000 tons of magnesium per annum at Hopton, near Wirksworth in Derbyshire.

The completion of the Hopton project

will make the U.K. largely independent of imports of this strategically important light metal. The plant will extract magnesium of 99·9 per cent purity from local dolomite by a process not previously operated on a commercial scale in Britain. The value of the completed plant to Magnesium Elektron is expected to be around £2,000,000.

Italian Copper Imports

According to statistics from Rome, Italian imports of crude copper during the first six months of this year amounted to 8,670·2 metric tons, valued at 3,228,820,000 lire, of which 1,475·4 metric tons, valued at 544,180,000 lire were temporary imports. The principal suppliers were Rhodesia and Nyasaland, with 3,191·4 tons, South Africa with 1,629·7 tons, and the United States with 3,086 tons.

Imports of refined copper in slabs, plates and ingots, etc., during the first six months of the year amounted to 101,892·5 metric tons, valued at 38,436,731,000 lire, of which 8,699·7 tons, valued at 3,358,941,000 lire were imported temporarily. The main suppliers of refined during the period were: France, with 2,446·1 tons; Belgium/Luxembourg, with 2,520·2 tons; the United Kingdom, with 7,643·4 tons; Congo Republic with 16,444·2 tons; Rhodesia and Nyasaland, with 16,075·4 tons; South Africa, with 3,139 tons; the United States, with 37,192·3 tons; Canada, with 3,333·9 tons; and Chile, with 9,528·1 tons.

"Soldeo Blando"

Solder users in all countries are familiar with the book "Notes on Soldering", which is available to them on application to the **Tin Research Institute** in London, and its offices in other countries. A translation of this book into the Spanish language has now been made in the Departamento de Metales no Férreos of the Consejo Superior de Investigaciones Científicas in Madrid. The Director of the Department, Dr. J. M. Sistiaga, says in a foreword: "El Departamento se congratula de poder ayudar de esta manera a la realización de una labor informativa que esperamos sea de gran utilidad a los científicos y técnicos de habla hispana".

The book consists of 112 pages of text, including 47 photographic illustrations and diagrams. It covers all aspects of soldering, including the theory and design of soldered joints, the basic steps in soldering, the wetting and penetrating action of solders upon metals, and the physical properties of all types of soft solders and soft soldered joints. There is a section on the soldering of stainless steel, aluminium, chromium, and other metals which require special treatment, and practical details of soldering techniques, used in a wide variety of industries, are also included. There is also a section on the making of soldered joints in lead pipes.

Russian Zinc

It is understood that Russian ordinary high grade zinc of 99·95 per cent purity has been delivered on the London Metal Exchange against the standard contract for the first time since it was registered by the Committee of the Exchange as constituting a good delivery some time ago, writes Comtelburo's metal correspondent. Any grade of metal commanding a premium over the standard market price, like the high grades of zinc or electrolytic copper wire bars, is seldom delivered on the market, dealers naturally wanting to obtain a premium by selling it outside the market to consumers.

Although the delivery of the Russian metal was not entirely unexpected, it nevertheless served to emphasize afresh the overall uninspiring zinc position. Arrivals of Russian zinc (all ordinary high grade) in the United Kingdom so far this year (January-July) have gathered momentum, totalling 15,378 tons. If this rate is maintained, the import total for the whole of 1960, at 17,946 tons, will be exceeded by several thousand tons. The delivery of this zinc clearly suggests that sellers are now unable to get a better price from consumers than that ruling on the London market for good ordinary brand metal of minimum 98 per cent purity because of the present adequacy of all grades to meet buyers' requirements.

Aluminium Building Components

At the forthcoming Building Exhibition, to be held at Olympia, London, next month, **Hunter Douglas Limited** are introducing the "Luxaflex" system of aluminium building components for use in modern architectural design. The aluminium building components can be utilized for infill panels, façade cladding, ventilation louvres, roofing, curtain walling and suspended ceilings. The Sun Louvre construction is also an extension of this system.

The main component of the system is formed from spring-tempered aluminium strips, the final profile having a width of $3\frac{5}{16}$ in. and weighing 0·6 lb/ft^2. The strip is chemically pretreated, followed by a prime coat and stove enamel finish for final baking under high temperature, giving the component a finish of extreme durability.

The main advantages of the building component are its lightness in weight, ease of erection, availability in unlimited lengths, inbuilt ventilation feature, and ease of maintenance. There is a wide range of colours available and the striking point of any construction utilizing this system is the attractive appearance of the completed job.

Also being shown for the first time is the "Luxaflex" Monocommando blind, specially designed for use in architectural and contract fields. The basic idea behind the Monocommando is that the usual system of control cords are dispensed with, and replaced by a single actuating rod which is operated by a chrome plated crank arm. This one control not only raises and lowers the blind, but enables the slats to be tilted to the required angle for light deflection.

Industrial Heating

An exhibition of industrial heating by electricity is being held in the Industrial Demonstration Centre at the North Western Electricity Board's Polygon Depot, Tower Street, Ardwick, Manchester. It is open daily (except Saturday) from 10 a.m. to 5 p.m. until Friday of next week (October 13).

The exhibition is designed to show the wide application of electricity to the heat-treatment of metals in the engineering industry. Demonstrations will be staged, at operating temperatures, of stress relieving, annealing and hardening, amongst other processes.

Birmingham News

Speaking at the monthly meeting of the Midland Regional Board for Industry, the chairman, Major C. R. Dibben, said the industrial outlook for the Midlands as far ahead as the middle of next year will almost certainly be set by trends in the next two months. The measures intro-

Forthcoming Meetings

October 9—Institute of Metals. Oxford Local Section. St. Edmund Hall, Oxford. Annual Dinner.

October 9—Institute of Metals. Scottish Local Section. Institution of Engineers and Shipbuilders, Elmbank Crescent, Glasgow. "Physical Methods of Analysis for Major Alloying Constituents." K. M. Bills. 6 p.m.

October 10—Institute of Metals. South Wales Local Section. Metallurgy Department, University College, Swansea. "Welding of Non-Ferrous Metals." J. G. Young. 6.30 p.m.

October 10 — Institution of Works Managers. Birmingham Branch. College of Technology, Gosta Green, Birmingham. "Is Management Too Technical for Human Relations?" J. Marsh. 7 p.m.

October 10 — Institution of Production Engineers. East and West Ridings Region. The Technical College, Waterdale, Doncaster. "Cold Extrusion." H. A. J. Dennison. 7 p.m.

October 11 — Manchester Metallurgical Society. Manchester Literary and Philosophical Society, George Street, Manchester. Presidential Address. W. L. Harper. 6.30 p.m.

October 11—Institute of Metal Finishing. Organic Finishing Group. 80 Fetter Lane, London, E.C.4. "Plastic Industrial Paints." D. H. Grover. 6.30 p.m.

October 12 — Institution of Plant Engineers. Glasgow Branch. Scottish Building Centre, 425 Sauchiehall Street, Glasgow. "Accident Prevention from the Plant Engineer's Standpoint." 7.15 p.m.

October 12—Institution of Production Engineers. London Graduate Section. 10 Chesterfield Street, Mayfair, London, W.1. "Can Electrochemical Cutting Compete?" D. J. Fishlock. 7.15 p.m.

October 12—Institute of Metals. Birmingham Local Section. College of Advanced Technology, Gosta Green, Birmingham. "Some Problems in the Development of Fuel Cells." A. D. S. Tantram. 6.30 p.m.

October 12—East Midlands Metallurgical Society. Derby and District College of Art, Derby. "Some Aspects of Metallurgical Training." M. I. McIntyre. 7.30 p.m.

October 12 — Liverpool Metallurgical Society. Department of Metallurgy, The University of Liverpool. Presidential Address. "Metallurgy and the Craftsman." F. R. Brace. 7 p.m.

October 13—West of England Metallurgical Society. College of Science and Technology, Ashley Down, Bristol, 7. "Creep: The Potential Influence of Theory in Practice." D. McLean. 7 p.m.

duced during the summer by the Chancellor of the Exchequer were making firms review their stock levels and expansion plans, and it was possible that the reviews would be reflected in time even more strongly in fewer new orders for machinery and equipment and building projects. Many industries in the region, said Major Dibben, were maintaining a high rate of activity. Capital goods manufacturers were busy, machine tool firms had plenty of work in hand, electrical companies were active and civil engineers were fully occupied.

Iron and steel producers are working below capacity. The motor trade does not need so much raw material as it did a year ago. Under-employment is prevalent in the rolling stock industry; competition is keen, and the British Transport Commission tends to build more rolling stock in its own workshops. In Midland industry generally there is still a shortage of skilled labour, but the demand for unskilled labour has eased considerably. Foundries producing light castings have spare capacity.

Shot-blast Abrasive

A non-metallic shot-blast abrasive, "No-Met", has been announced by **Bradley's (Darlaston) Limited,** a member of the Staveley group of companies. This new non-metallic abrasive has been developed, states the company, to fulfil the demand for a cheap expendable abrasive. It is free of silica and complies with the shot-blasting regulations.

A Lecture Course

A course of ten lectures on "Practical Implications of Metal Physics" is to be given at the **College of Advanced Technology,** Birmingham, on successive Tuesday evenings at 6.30 p.m., beginning on Tuesday next, October 10.

The course is intended for chemists, metallurgists and physicists engaged in research and development or materials control. Each meeting will last for about two hours and will include a lecture, followed by a discussion. The fee for the whole course is £2 10s. 0d.

U.K. Metal Stocks

Stocks of refined tin in London Metal Exchange official warehouses at the end of last week fell 86 tons to 5,238 tons, comprising London 2,250, Liverpool 1,549 and Hull 1,439 tons.

Copper stocks rose 250 tons to 22,594 tons, comprising London 450, Liverpool 18,094, Birmingham 50, Manchester 3,925, Hull 50 and Glasgow 25 tons.

Lead duty-free stocks fell 5 tons to 7,027 tons, comprising London 6,677, Glasgow 200, and Swansea 150 tons. In-bond stocks remained at 3,602 tons, all supplies in London.

Zinc duty-free stocks rose 367 tons to 4,044 tons, comprising London 2,643, Glasgow 46, Hull 550, Manchester 325, Liverpool 55, and Avonmouth 425 tons. In-bond stocks fell 5 tons to 3,153 tons, all supplies in London.

Plans to Promote Lead

Formation of the **European Lead Development Committee** to co-ordinate and expand promotional work throughout Europe has been announced following meetings in Rome between representatives of the French, German, Italian, Spanish and United Kingdom lead development associations and the Belgian and Swedish lead producers. The L.D.A., London, will be responsible for the secretarial work of the new committee under the guidance of a steering group comprising France, Germany, Italy and the United Kingdom.

The consumption of lead in all forms in Europe has risen in the last four years by about 120,000 tons (11 per cent) to 1,200,000 metric tons in 1960. Preliminary figures for the first half of 1961, prepared by the Committee, show that the growth is continuing for Europe as a whole, despite some levelling off in the United Kingdom, where consumption per capita is the highest in the world.

This expansion in consumption is the result of the steady growth of most uses. Batteries now consume 30 per cent more lead than four years ago, the rise, which is expected to continue, reflecting the more widespread use of motor cars. The use of lead for radiation shielding is also expanding rapidly, but precise figures are not available in all countries.

The meeting completed preliminary arrangements for the first International Conference on Lead to be held in London from May 22 to 25, 1962. The emphasis will be in the use of lead for batteries, cables and nuclear shielding, and other sessions will cover economic trends and research. The full programme will be announced later.

Technical aspects of many lead uses were examined by the Committee. There are interesting differences in the techniques used in various countries for lead cable sheathing and these will be described in special reports shortly to be issued. In sheet and pipe, too, there are striking contrasts in applications which will be illustrated in forthcoming international publications, showing lead in modern building. Everywhere, the need for better sound insulation is creating new demands for lead which, because of its weight and limpness, is specially suitable as a sound barrier.

The future activities of the Committee include the publication of technical and promotional booklets and a European lead bulletin in French, German, Italian and English.

Metal Plant for Brazil

The East Asiatic Company Limited and the metal firm of Paul Bergsoe and Son, both of Copenhagen, are jointly establishing a metal-producing plant in Sao Paulo, Brazil, according to a spokesman for the Bergsoe company. The plant, being constructed by the Danish engineering firm of Christiani and Nielsen, is expected to be in operation by December this year.

It will have an initial capacity of about 2,000 tons annually of whitemetal, tin solder, printing metal, and other lead alloys as well as aluminium and zinc alloys. The plant will operate under the name of Fundicao de Metais Bera Limitada.

Aluminium in Germany

According to reports from New York, Aluminium Limited have announced the acquisition of a modern aluminium foundry at Uphusen, near Bremen. The company's fully owned subsidiary, Aluminium Werke Nuernberg G.m.b.H., has taken over operation of the foundry, which is equipped to produce aluminium sand castings, permanent mould castings, and die-castings.

Together with the Nuernberg foundry and piston factory, which is also being expanded, the new plant will more than double Aluminium Limited's total foundry capacity in Germany to nearly 10,000 tons of castings.

The company also disclosed that construction work on the expansion of its sheet and strip-rolling mill at Goettingen, West Germany, is proceeding according to schedule. When complete, next year, this plant will treble the company's alu-

Trade Publications

Metal Powders. — Powder Metallurgy Limited, Berk House, 8 Baker Street, London, W.1.

This booklet describes the types of metal powders which are manufactured and marketed by the company. The information provided is of a general nature, and notes are given concerning the *Metal Powder Report*, a monthly technical abstract bulletin concerning metal powders, another publication by the company.

Cutting Fluids.—Fletcher Miller Limited, Alma Mills, Hyde, Cheshire.

This year's edition of this booklet enumerates the 43 grades of cutting fluid most in demand, setting against each their type, properties, and applications. There is also a fold-out recommendations chart, a section wholly given over to filtration and cleaning equipment for the machine shop, and some useful data on metals that affect cutting fluid efficiency. The booklet has 64 pages and there are also many excellent illustrations.

Plate Levelling Machines.—Head Wrightson Machine Company Ltd., Middlesbrough.

In a new four-page coloured brochure is described the range of plate levelling machines available from this company for shipyards, plate mills, etc. Illustrations are given of 7-roll reversing machines, 9- and 11-roll single pass levellers for heavy duty, as well as the principal features of the machines.

Degreasing Plant. — Imperial Chemical Industries Limited, General Chemicals Division, Millbank, London, S.W.1.

A leaflet gives details of a new addition to the division's range of degreasing plant. Basically, the type H plant, which is described in the leaflet, is a standard I.C.I. degreasing plant with a built-in lift to give either semi-automatic or fully automatic working.

Forging Close to Finished Form.—High Duty Alloys Limited, Slough, Bucks.

This booklet is the first of a series to be published by this company. It deals with advances in drop forging and presents photographs of some of the applications of Hiduminium for the aircraft and allied industries. The object of this series of booklets is to provide a general picture of what forging can now do towards increasing production and reducing costs.

Gear Pumps.—The Brooke Tool Manufacturing Company Ltd., Warwick Road, Greet, Birmingham, 11.

The new brochure issued by this company covers 34 pages in which full details, illustrations and diagrams are given of the wide range of gear pumps manufactured by the company.

minium sheet capacity in Germany to about 25,000 tons per year, thus providing an additional outlet for Alcan primary metal from Canada. New plant investment in Germany, under Aluminium Limited's current programme, amounts to about $12,000,000—some of which will be financed locally.

Corrosion Problems

On Wednesday, October 18 next, at 14 Belgrave Square, London, S.W.1, the Corrosion Group of the **Society of Chemical Industry** will hold a meeting at which the subject for discussion will be "Volatile Corrosion Inhibitors". Mr. E. Ll. Evans will speak on "Principles" and Mr. R. I. Barraclough will follow with "Practical Applications". The meeting will commence at 6 p.m.

New Number

On October 25 next, at 1 p.m., the telephone number of **The A.P.V. Company Ltd.** and **A.P.V.-Paramount Ltd.** will be changed to Crawley 27777 when Crawley's telephone service becomes automatic.

A Birmingham Meeting

Speaking on the origins of strength in alloys, Prof. R. W. K. Honeycombe last week addressed the Birmingham Local Section of the **Institute of Metals**. Dealing with the role that dislocations play in the strength and ductility of alloys, he touched on the Cottrell theory and the migration of solute atoms to dislocations which restricts dislocation movement. A second factor which imposed restrictions on such movements was precipitation at dislocations, which had the effect of "pegging" them. Finally, he emphasized the importance of stacking faults as a further factor tending to minimize dislocation movement.

This was the first meeting of the season, the chairman being Dr. I. G. Slater, and a number of interesting points were raised in the discussion which followed.

Malayan Tin Shipments

The Straits Trading Company reports that Malayan tin shipments in September amounted to 7,689½ tons from Penang, of which the United Kingdom took 10 tons, U.K. options 45, U.S. 4,407, the Continent 1,233, Canada 482½, Japan 750¾, the Pacific 17½, India 479¼, South America 114, Africa 10, Australasia 86, and the Middle East 54¾.

Shipments from Singapore during the period totalled 12¼ tons, of which the Pacific took 11¼ tons and India ¼ ton.

Canadian Production

Statistics from Ottawa show that production of copper and silver was smaller in July and the January-July period this year as compared to last, while output of nickel and lead was larger in both periods. Output of zinc was up in the month and down in the cumulative period.

July production of these five metals was: copper 37,927 tons (38,452 in July 1960); nickel, 20,490 tons (17,821); silver, 2,462,870 fine ounces (2,919,664); lead, 18,630 tons (18,039); and zinc, 33,881 tons (31,711).

Seven-month totals were: copper, 255,560 tons (259,758 a year ago); nickel, 129,810 tons (122,549); silver 18,177,653 fine ounces (19,193,349); lead, 128,657 tons (117,968); and zinc, 217,786 tons (237,726).

MEN and Metals

At present deputy managing director of the marine division of Richardsons Westgarth and Company, **Mr. H. Kay** has been appointed assistant managing director of the engineering division of Tube Investments Limited.

Following the recent announcement that the Garrard Engineering and Manufacturing Company Limited had become a wholly owned subsidiary of the Plessey Company Limited, the formation of a reconstituted board of directors is announced by Plessey as follows:—**Mr. A. E. Underwood** (chairman), **Mr. Hector V. Slade** (managing director), **Mr. K. J. Slade, Mr. J. Tyldesley, Mr. John A. Clark,** and **Mr. Michael W. Clark.**

The Plessey Company also announces that **Sir William Stanier** has resigned from the Garrard board, and has been offered and has accepted an appointment as a director of Machine Products Limited. **Mr. Donald F. Brown** has also resigned from the Garrard board, and has been invited to join the board of Hawley Products Limited, an invitation which he has accepted. Both Machine Products Limited and Hawley Products Limited are members of the Plessey group of companies.

Director and general manager of the Projectile and Engineering Company Limited, **Mr. E. L. Tuff,** M.I.Prod.E., has been appointed deputy managing director. He has been with the company for 30 years, and was works manager before being appointed to the board in November 1953. He assumed the duties of general manager in September 1958.

Formerly general manager of Head Wrightson Stockton Limited, **Mr. R. B. W. Bolland** has been appointed London manager of Head Wrightson and Company Limited.

It is announced that **Dr. W. J. Bates,** Ph.D., B.Sc., has joined R. and J. Beck Limited as chief engineer. He leaves Bristol University to lead the company's design team and, pending completion of the company's new factory at Watford, will be located at Lister Works, Dickenson Street, London, N.W. R. and J. Beck are one of the Griffin and George group of companies.

We understand that **Mr. M. A. Mawby** has been appointed chairman of Comalco Industries Pty., the parent company in the aluminium complex which has been set up by the Consolidated Zinc Corporation and Kaiser Aluminum and Chemical Corporation.

At the annual general meeting of the British Standards Institution, held last week, **Mr. Geoffrey Cunliffe** (managing director of Norcros Limited) was elected President of the Institution, and is also chairman of the General Council of the Institution. The former President, **Mr. R. E. Huffam,** was elected a Deputy-President, and **Sir Herbert Manzoni** and **Mr. John Ryan** were re-elected as Deputy-Presidents. **Mr. A. D. Bonham-Carter** was elected chairman of the Institution's Finance Committee, and **Sir Anthony H. M. Bowlby,** chairman of the Engineering Divisional Council of the Institution.

Appointed to the board of Armstrong Whitworth (Metal Industries) Limited, **Mr. Austin W. Scott,** B.Sc., A.M.I.Mech.E., joined the company in 1949 and will continue to retain the position he has held for the past two years as works manager of the Jarrow Foundry Division.

Formerly an employee of the company, **Mr. William John Crockett** has been appointed managing director of Wright and Platt Limited. He is also chairman and managing director of Crockett Lowe Limited, Robinson and Knee Limited, and C.L. Developments Limited.

At the meeting of the Birmingham Local Section of the Institute of Metals, held last week, **Mr. L. G. Beresford,** B.Sc., F.I.M., was elected vice-chairman of the section. Mr. Beresford is a Past-President of the Birmingham Metallurgical Society and is also Editor of METAL INDUSTRY.

News from the Griffin and George group of companies is that **Mr. Dennis S. Beard,** Ph.D., A.Inst.P., A.R.C.S., B.Sc., has been appointed to the board of Griffin and George (Sales) Limited in the capacity of technical sales director.

Formerly Yorkshire area manager, **Mr. R. H. Wormley** has now been appointed home sales manager of Associated British Machine Tool Makers Limited.

It has been announced by Tube Investments Limited that **Dr. J. W. Menter,** M.A., D.Sc., F.Inst.P., has been appointed director of the T.I. Research Laboratory at Hinxton Hall, near Cambridge.

In addition to his present appointment as an overseas director, **Dr. A. Caress** is to become research and development director of Imperial Chemical Industries Limited. He succeeds **Dr. J. Ferguson,** who is retiring from the board after 33 years' service with the company.

News from the Firth Cleveland Group is that **Mr. William H. Rigg** has been appointed managing director of Firth Cleveland Tools, a member of the group. Mr. Rigg will operate from the company's Tipton works.

Managing director of Morgan Refractories, **Mr. J. F. King** has been appointed a director of The Morgan Crucible Company Limited.

Metal Market News

THE early part of last week saw further weakness in the price of standard copper on the London Metal Exchange, and on Tuesday afternoon cash was quoted at £222 and three months at £226 10s. 0d. At those levels, however, buyers appeared and, due perhaps in the main to bear covering, there was a modest recovery on the following day. Thursday saw the improvement carried further and at midday the quotations stood at £225 10s. 0d. and £229 5s. 0d. on a turnover of well over 2,000 tons including Kerb business. This dealing after the ring amounted probably to at least 500 tons but the quotation dropped rather dramatically by £1. The contango has remained relatively wide, thanks, perhaps, to a further increase of 260 tons in L.M.E. stocks to 22,344 tons. Consumer demand for the metal still hangs fire, due partly to the fact that the users are still hoping and expecting that the price will go lower. Business in semis is not thought to be very brisk, one suggestion being that doubts about the effect on the non-ferrous industry of entering into the Common Market is putting a brake on activity. There may be something in this, but more likely is the fact that the movement towards reduction of stocks is still under way and buyers are determined to run down their holdings to the lowest possible level.

In total, the turnover in standard copper amounted to about 11,200 tons for the week and losses amounted to £3 15s. 0d. for cash and £4 10s. 0d. for three months. At the close of business on Friday afternoon, prompt copper was quoted at £223 and forward at £226 10s. 0d., both these prices being above the lowest levels reached during the week's trading. Business in the States appears to be going on quite well. There has certainly been a marked improvement during the past six months, but latterly the weakness of the London market has rather upset the quotation for copper scrap and the margin below the custom smelters' price has widened. Whether any reduction will come in the smelters' quotation remains to be seen. Probably not, for, as already suggested, demand for copper is quite good, but in the past weakness in London has sometimes led to a drop in the American price. As always when the price in Whittington Avenue declines to a point which makes a wide gap between London and the current quotation in New York, suggestions have been made that sales might be made to the United States and a tonnage withdrawn from the L.M.E. stocks for shipment across the Atlantic. One objection to this would seem to be that the L.M.E. tonnage comprises almost entirely fire refined quality, which is not popular in America.

The tin market has continued to show nervousness and uncertainty although it is now known that the tin release Bill will be passed by Congress during the present session. On weekdays, consumer buying has been in evidence, but there is an air of caution in all these operations, and the fact that Congress adjourned without taking any action on tin appears to have done nothing to help the market. On a turnover of 2,920 tons cash gained £2 to £954, while three months lost £2 to £962. Both zinc and lead were very disappointing, trading in zinc amounting to no more than a turnover of 5,050 tons, which left cash £1 17s. 6d. down at £73 10s. 0d. and three months £1 15s. 0d. lower at £73 15s. 0d. In lead, some 10,650 tons changed hands, both positions losing 22s. 6d. at £63 for cash and £64 15s. 0d. three months.

New York

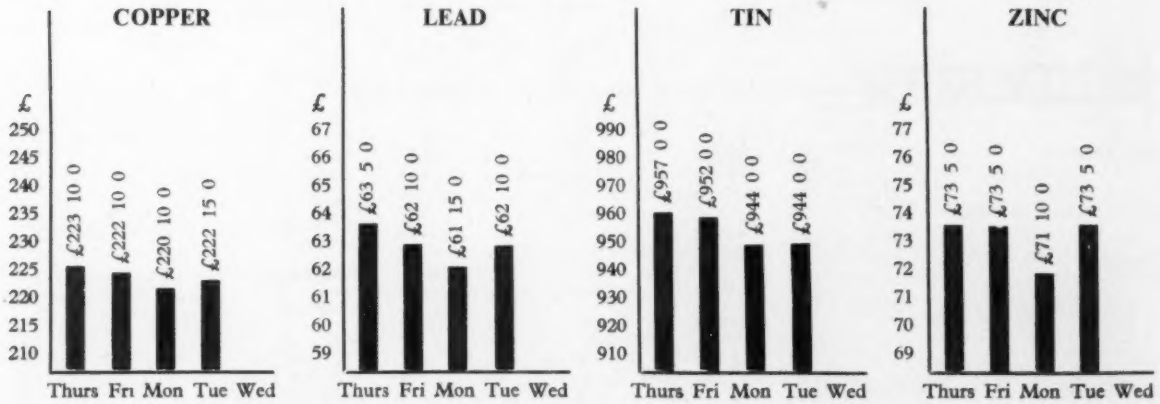
Copper futures, after early steadiness, eased on liquidation. Dealings were fair. In physical copper, dealer copper in the domestic sector was reported available at 30¾ cents per lb. delivered. Export copper was softer and quiet. Leading custom smelters and producers said that their copper price at 31 cents was steady and they were sold out for October. November enquiries were developing, custom smelters selling at a flat price of 31 cents or at an average price basis. Producers sell at the price on the day of shipment. Tin was slightly softer and quiet. Spot to November was offered at 122 cents/lb., December 121⅞ and January 121¾ cents.

United States aluminium die-castings output this year is expected to top last year's volume of 182,750 tons, but zinc die-castings production will fall short of the 1960 total of 312,500 tons by about 10 per cent, it is forecast by the American Die Casting Institute on the eve of its annual meeting. The A.D.C.I. also looks for an improvement in the output of magnesium and brass die-castings but says "over-all die-castings production this year will be slightly below 1960 levels".

Regarding next year, the Association said: "The die-casters feel there is every reason to believe that 1962 will see the production of aluminium die-castings at a record high level and that zinc die-casting output will approach the 350,000 ton level normal for a year of high automotive production. With automobile production next year estimated at over 6,500,000 cars and with a sizeable increase in the use of zinc die-castings on the new models, it appears that zinc die-casting consumption will be much improved in 1962."

London Metal Exchange

Thursday 28 September to Tuesday 3 October 1961



NON-FERROUS

PRIMARY METALS

All prices quoted are those available at 2 p.m. 3/10/61

		£	s.	d.
Aluminium Ingots	ton	186	0	0
Antimony 99·6%	„	237	10	0
Antimony Metal 99%	„	230	0	0
Antimony Oxide Commercial	„	194	10	0
Antimony White Oxide	„	212	0	0
Arsenic	„	400	0	0
Bismuth 99·95%	lb.		16	0
Cadmium 99·9%	„		11	0
Calcium	„	2	0	0
Cerium 99%	„	15	0	0
Chromium	„		6	11
Cobalt	„		12	0
Columbite	per unit		8	0	0
Copper H.C. Electro	ton	222	15	0
Fire Refined 99·70%	„	221	0	0
Fire Refined 99·50%	„	220	0	0

		£	s.	d.
Copper Sulphate	ton	77	0	0
Germanium	grm.		—	
Gold	oz.	12	10	0¾
Indium	„		10	0
Iridium	„	24	0	0
Lanthanum	grm.		15	0
Lead English	ton	62	10	0
Magnesium Ingots	lb.			
99·8%	„		2	2½
99·9+%	„		2	3
Notched Bar	„		2	9½
Powder Grade 4	„		5	6
Alloy Ingot, AZ91X		1	11½-2	1½
Manganese Metal	ton	280	0	0
Mercury	flask	62	0	0
Molybdenum	lb.	1	15	0
Nickel	ton	660	0	0
F. Shot	lb.		5	11
F. Ingot	„		5	11
Osmium	oz.	20	0	0
Osmiridium	„		—	

		£	s.	d.
Palladium	oz.	9	0	0
Platinum	„	30	5	0
Rhodium	„	46	0	0
Ruthenium	„	16	0	0
Selenium	lb.	2	6	6
Silicon 98%	ton	123	0	0
Silver Spot Bars	oz.		6	7¾
Tellurium Sticks	lb.	2	0	0
Tin	ton	944	0	0
***Zinc**				
Electrolytic	ton		—	
Min 99·99%	„		—	
Virgin Min 98%	„	73	5	7½
Dust 95/97%	„	118	10	0
Dust 98/99%	„	124	10	0
Granulated 99+%	„	98	5	7½
Granulated 99·99+%	„	111	2	6

**Duty and Carriage to customers' works for buyers' account.*

INGOT METALS

All prices quoted are those available at 2 p.m. 3/10/61

Aluminium Alloy (Virgin)	£	s.	d.
B.S. 1490 L.M.5 ton	210	0	0
B.S. 1490 L.M.6 „	202	0	0
B.S. 1490 L.M.7 „	216	0	0
B.S. 1490 L.M.8 „	203	0	0
B.S. 1490 L.M.9 „	203	0	0
B.S. 1490 L.M.10 „	221	0	0
B.S. 1490 L.M.11 „	215	0	0
B.S. 1490 L.M.12 „	223	0	0
B.S. 1490 L.M.13 „	216	0	0
B.S. 1490 L.M.14 „	224	0	0
B.S. 1490 L.M.15 „	210	0	0
B.S. 1490 L.M.16 „	206	0	0
B.S. 1490 L.M.18 „	203	0	0
B.S. 1490 L.M.22 „	210	0	0
Aluminium Alloys (Secondary)			
B.S. 1490 L.M.1 ton	152	0	0
B.S. 1490 L.M.2 „	152	0	0
B.S. 1490 L.M.4 „	161	0	0
B.S. 1490 L.M.6 „	176	0	0
***Aluminium Bronze**			
BSS 1400 AB.1 ton	236	0	0
BSS 1400 AB.2 „	243	0	0

	£	s.	d.
***Brass**			
BSS 1400-SCB2 ton	172	0	0
SCB3 „	164	0	0
***Gunmetal**			
R.C.H. 3/4% ton „		—	
(85/5/5/5) LG2 „	209	0	0
(86/7/5/2) LG3 „	219	0	0
(88/10/2/1½) LG1 „	280	0	0
***Manganese Bronze**			
BSS 1400 HTB1 „	189	0	0
BSS 1400 HTB2 „	209	0	0
BSS 1400 HTB3 „	225	0	0
Nickel Silver			
Casting Quality 12% „	260	0	0
„ „ 16% „	270	0	0
„ „ 18% „	315	0	0
***Phosphor Bronze**			
B.S.1400P.B.1.(A.I.D. released) „	311	0	0
B.S. 1400 L.P.B.1 „	235	0	0

**Average prices for the last week-end.*

Phosphor Copper	£	s.	d.
10% ton	255	0	0
15% „	258	0	0
Phosphor Tin			
5% „	1030	0	0
Silicon Bronze			
BSS 1400-SB1 „	275	0	0
Solder, soft, BSS 219			
Grade C Tinmans „	424	15	0
Grade D Plumbers „	336	0	0
Grade M „	469	10	0
Solder, Brazing, BSS 1845			
Type 8 (Granulated) lb.		—	
Type 9 „ „		—	
Zinc Alloys			
BSS 1004 Alloy A ton	104	12	6
BSS 1004 Alloy B „	108	12	6
Sodium-Zinc lb.		2	6

SCRAP METALS

Merchants' average buying prices delivered, per ton, 3/10/61

Aluminium	£
New Cuttings	134
Old Rolled	100
Segregated Turnings	72
Brass	
Cuttings	155
Rod Ends	139
Heavy Yellow	133
Light	128
Rolled	142
Collected Scrap	129
Turnings	133

Copper	£
Wire	193
Firebox, cut up	191
Heavy	190
Light	188
Cuttings	198
Turnings	184
Braziery	158
Gunmetal	
Gear Wheels	192
Admiralty	192
Commercial	176
Turnings	171

Lead	£
Scrap	54
Nickel	
Cuttings	—
Anodes	590
Phosphor Bronze	
Scrap	176
Turnings	171
Zinc	
Remelted	66
Cuttings	55
Old Zinc	35

METAL PRICES

SEMI-FABRICATED PRODUCTS

Prices vary according to dimensions and quantities. The following are the basis prices for certain specific products

		£ s. d.
Aluminium		
Sheet 10 S.W.G.	lb.	2 10½
Sheet 18 S.W.G.	„	3 0½
Sheet 24 S.W.G.	„	3 3½
Strip 10 S.W.G.	„	2 10½
Strip 18 S.W.G.	„	2 11½
Strip 24 S.W.G.	„	3 1
Circles 22 S.W.G.	„	3 4½
Circles 18 S.W.G.	„	3 3½
Circles 12 S.W.G.	„	3 2½
Plate as rolled	„	2 10
Sections	„	3 4
Wire 10 S.W.G.	„	3 1½
Tubes 1 in. o.d. 16 S.W.G.	„	4 4
Aluminium Alloys		
BS 1470. HS19W.		
Sheet 10 S.W.G.	„	3 3
Sheet 18 S.W.G.	„	3 5½
Sheet 24 S.W.G.	„	4 1
Strip 10 S.W.G.	„	3 3
Strip 18 S.W.G.	„	3 4½
Strip 24 S.W.G.	„	4 0½
BS1477. HP30M. Plate as rolled	„	3 1
BS1470. HC15WP.		
Sheet 10 S.W.G.	„	4 3
Sheet 18 S.W.G.	„	4 8½
Sheet 24 S.W.G.	„	5 8½
Strip 10 S.W.G.	„	4 4
Strip 18 S.W.G.	„	4 8½
Strip 24 S.W.G.	„	5 4½

		£ s. d.
Aluminium Alloys—cont.		
BS1477. HPC15WP. Plate heat treated	lb.	3 10½
BS1475. HG19W. Wire 10 S.W.G.	„	4 2
BS1471. HT19WP. Tubes 1 in. o.d. 16 S.W.G.	„	5 5
BS1476. HE19WP. Sections	„	3 4
Split tube		
19 S.W.G. (¼″)	„	4 2
20 S.W.G. (⅜″)	„	3 11
21 S.W.G. (½″)	„	4 1
22 S.W.G. (¼″)	„	4 11
Welded tube 14 to 20 S.W.G. (sizes ½″ to 1½″)	„	3/10½ to 5/8½
Brass		
Tubes	lb.	1 9½
Brazed Tubes	„	3 1½
Drawn Strip Sections	„	3 1½
Sheet	ton	190 15 0
Strip	„	190 15 0
Extruded Bar	lb.	1 11¾
Condenser Plate (Yellow Metal)	ton	182 0 0
Condenser Plate (Naval Brass)	„	196 0 0
Wire	lb.	2 7⅞

		£ s. d.
Beryllium Copper		
Strip	lb.	1 4 11
Rod	„	1 1 6
Wire	„	1 4 9
Copper		
Tubes	lb.	2 3
Sheet	ton	256 5 0
Strip	„	256 5 0
H.C. Wire	„	275 5 0
Cupro Nickel		
Tubes 70/30	lb.	3 8⅜
Lead		
Pipes (London)	ton	107 0 0
Sheet (London)	„	104 15 0
Tellurium Lead	„	£6 extra
Nickel Silver		
Sheet and Strip 10%	lb.	3 11½
Wire 10%	„	4 4½
Phosphor Bronze		
Wire	„	4 1½
Titanium (1,000 lb. lots)		
Billet 4½″ to 18″ dia.	lb.	47/- 48/-
Rod ½″ to 4″ dia.	„	85/- 53/-
Wire ·036″-232″ dia.	„	159/- 99/-
Strip ·001″ to ·048″	„	350/- 68/-
Sheet 8′ × 2′. 20 gauge	„	73/-
Tube, representative average gauge	„	198/-
Extrusions	„	90/-
Zinc		
Sheet	ton	109 10 0
Strip	„	nom.

FOREIGN QUOTATIONS

Latest available quotations for non-ferrous metals with approximate sterling equivalents based on current exchange rates

Belgium	fr/kg	£/ton
Copper: electrolytic	32.50	237 11
Tin	134.30	981 8

Canada	c/lb	£/ton
Aluminium	26.00	210 12
Copper: electrolytic	30.00	243 0
Lead	10.50	81 0
Nickel	70.00	567 0
Zinc: Prime western	12.00	97 4
High grade 99.95	12.60	102 1
High grade 99.99	13.00	105 6

France	fr/kg	£/ton
Aluminium	2.43	179 11
Antimony 99·0	2.80	206 18
Cadmium	16.25	1,200 17
Copper: electrolytic	3.28	242 8
Lead	.95	70 4
Nickel	9.00	665 2
Tin	13.75	1,016 2
Zinc: Thermic	1.11	82 0
Zinc: electrolytic	1.19	87 5
Scrap		
Copper: electrolytic	2.80	206 18
Heavy copper	2.80	206 18
No. 1 copper wire	2.65	195 17
Brass rod ends	2.12	156 13
Zinc castings	.87	64 5
Lead	.87	64 5
Aluminium	1.80	133 0

Italy	lire/kg	£/ton
Aluminium	370	216 1
Antimony 99·0	485	283 4
Copper: wire bars 99.9	450	262 16
Lead	165	96 8
Nickel	1,300	805 14
Tin	1,840	1,074 11
Zinc: electrolytic	181	105 15
Scrap		
Aluminium soft sheet clippings (new)	305	178 2
Lead, soft, first quality	137	80 0
Lead, battery plates	77	45 19
Copper, first grade	370	216 0
Bronze, commercial gunmetal	420	245 7
Brass: heavy	275	160 12
Brass: light	260	152 16
Brass, bar turnings	275	160 12
Old zinc	107	62 10

Switzerland	fr/kg	£/ton
Aluminium	2.50	210 5
Copper: electrolytic	2.98	250 12
Lead	.80	67 5
Nickel	7.50	630 15
Tin	11.70	983 18
Zinc: High grade 99.99	1.03	86 12

Japan	Yen per metric ton
Scrap	
Copper: electrolytic	289,000
Copper wire No. 1	268,000
Copper wire No. 2	260,000
Heavy copper	260,000
Light copper	237,000
Brass, new cuttings	197,000
Red brass scrap	217,000

West Germany *Scrap*	D-marks per 100 kilos	£/ton
Used copper wire	225	205 0
Heavy copper	220	200 8
Light copper	190	173 1
Heavy brass	145	132 1
Light brass	110	100 5
Soft lead	50	45 11
Zinc	50	45 11
Used aluminium unsorted	75	68 6

United States	c/lb	£/ton
Aluminium	26.00	207 4
Antimony 99·0	32.50	259 0
Cadmium	160.00	1,275 4
Copper: electrolytic	31.00	247 10
Lead	11.00	87 13
Nickel	81.25	647 11
Tin	122.50	976 6
Zinc: electrolytic	12.50	99 12

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ISSUED CAPITAL •	AMOUNT OF SHARE	NAME OF COMPANY	MIDDLE PRICE 2 OCTOBER +RISE—FALL	DIV. FOR LAST FIN. YEAR	DIV. FOR PREV. YEAR	DIV. YIELD	1961 HIGH	1961 LOW	1960 HIGH	1960 LOW
£	£			Per cent	Per cent					
4,435,792	1	Amalgamated Metal Corporation ...	30/– —6d.	11	9	7 6 9	33/9	26/3	35/–	26/6
400,000	2/–	Anti-Attrition Metal	1/3	NIL	4	NIL	1/3½	0/9	1/6	0/9
43,133,593	Stk. (£1)	Associated Electrical Industries ...	30/1½xd —4/3	15	15	9 18 3	54/10½	30/1½	67/3	38/3
3,895,963	1	Birfield	63/3 —9d.	10	15‡	3 3 3	78/9	45/–	51/3	29/–
4,795,000	1	Birmid Industries	76/– —1/–	20	20D	5 5 3	103/–	71/3	74/9	56/–
8,445,516	Stk. (10/–)	Birmingham Small Arms	20/– —9d.	17½QT	12½	5 16 9	36/10½	20/–	30/6	18/3
203,150	Stk. (£1)	Ditto Cum. A. Pref. 5%	12/6	5	5	8 0 0	14/6	12/3	17/4½	14/9
476,420	Stk. (£1)	Ditto Cum. B. Pref. 6%	15/6 —6d.	6	6	7 14 9	17/6	15/6	20/–	17/1½
1,500,000	Stk. (£1)	British Aluminium Co. Pref. 6% ...	15/9	6	6	7 10 0	18/–	15/3	21/1½	17/7½
18,846,647	Stk. (£1)	British Insulated Callender's Cables	56/– —1/–	13½	13½	4 16 6	62/3	49/–	61/4½	47/–
7,670,837	5/–	British Oxygen Co. Ltd., Ord. ...	17/6 —9d.	16D	16	3 1 0	28/4½	17/6	35/–	19/10½
1,200,000	Stk. (5/–)	Canning (W.) & Co.	15/–	15⅝	25+•2½C‡	5 5 9	20/9	13/7½	19/9	13/7½
60,484	1/–	Carr (Chas.)	1/1½	NIL	12½	—	1/7½	10½d.	2/3	1/–
555,000	1	Clifford (Chas.) Ltd.	29/–	12	10	8 5 6	31/–	26/–	35/–	28/9
45,000	1	Ditto Cum. Pref. 6%	15/–	6	6	8 0 0	15/3	15/–	16/–	15/10½
1,166,000	Stk. (2/–)	Clifford Components V	8/– —3d.	25•2½C	25•2½C	6 5 0	10/1½	7/3	11/9	6/10½
300,000	2/–	Coley Metals	3/3 +3d.	15	15	9 14 6	4/5½	3/–	5/–	3/4½
10,185,696	1	Cons. Zinc Corp.†	64/– —2/–	20	15	6 5 0	81/6	63/–	80/9	59/6
5,399,056	5/–	Davy-Ashmore	38/3	27½	22½	3 13 3	44/6	32/6	147/3	99/6
8,000,000	5/–	Delta Metal	21/6 —4½d.	20	17½	4 13 0	27/7½	19/9	28/3	18/6
5,296,550	Stk. (£1)	Enfield Rolling Mills Ltd.	37/9 —3d.	15	15	7 19 0	52/3	37/6	56/9	45/–
1,155,000	1	Evered & Co.	43/6	10	10 ϕB	4 12 0	45/9	42/6	42/9	29/3
18,000,000	Stk. (£1)	General Electric Co.	26/– —1/–	10	10	7 13 9	39/6	25/9	47/9	29/–
1,500,000	Stk. (10/–)	General Refractories Ltd.	53/3 —6d.	25	20	4 13 9	65/–	42/9	52/6	40/–
937,500	5/–	Glacier Metal Co. Ltd.	18/3	15	13	4 2 3	21/1½	13/9	16/1½	11/1½
2,750,000	5/–	Glynwed Tubes	23/4½xd —7½d.	22½	25¶	4 16 3	30/3	23/–	27/6	17/–
7,228,065	10/–	Goodlass Wall & Lead Industries ...	30/– —1/–	15	19L	5 0 0	44/9	30/–	41/9	33/–
696,780	10/–	Greenwood & Batley	16/3	15	30‡	9 4 6	29/6	16/3	33/6	29/1½
792,000	5/–	Harrison (B'ham) Ord.	9/–	•10	•20‡	5 11 0	14/6	8/9	15/10½	11/9
150,000	1	Ditto Cum. Pref. 7%	18/–	7	7	7 15 6	20/4½	18/–	23/6	22/–
1,612,750	5/–	Heenan Group	13/6 +3d.	13	15	4 16 3	17/1½	10/6	13/–	9/10½
251,689,407	Stk. (£1)	Imperial Chemical Industries ...	59/3xd —5/–	13⅜	11½	4 12 9	81/6	59/3	76/6	54/–
34,736,773	Stk. (£1)	Ditto Cum. Pref. 5%	14/9	5	5	6 15 6	16/–	13/10½	18/–	15/4½
29,196,118	••	International Nickel	145 —1½	$1.60	$1.50	1 17 6	160	104	105	84⅜
6,000,000	1	Johnson, Matthey & Co.	67/9 —3/3	15	12	4 8 6	75/–	57/6	67/6	44/9
600,000	10/–	Keith, Blackman	17/6	17½	17½E	10 0 0	21/6	16/6	32/6	17/6
320,000	4/–	London Aluminium	11/6	13	12	4 10 6	15/–	8/6	12/6	7/10½
1,530,024	1	McKechnie Bros. A Ord.	33/9	12½K	17½F	7 8 3	53/3	33/6	69/3	55/–
1,108,268	5/–	Manganese Bronze & Brass	12/6 —1/–	20⅝	20⅝	8 6 9	18/6	11/6	18/6	13/4½
50,628	6/–	Ditto (7½% N.C. Pref.)	5/3 —3d.	7½	7½	8 10 6	6/–	5/–	6/6	5/9
26,361 444	Stk. (£1)	Metal Box	82/–	12	12M	2 19 3	100/9	68/3	84/3	61/–
415,760	Stk. (2/–)	Metal Traders	7/6	50	50	3 6 9	8/9	6/9	10/9	7/1½
240,000	1	Mint (The) Birmingham	33/9	15G	12½	5 18 3	35/9	24/–	39/–	33/6
80,000	5	Ditto Pref. 6%	71/6	6	6	8 7 9	77/6	71/6	80/–	75/–
274,152	1/–	Minworth Metals	5/6	30	30S	5 9 0	6/3	4/6⅜	5/2½	3/10½
5,187,938	Stk. (£1)	Morgan Crucible A	60/3 +6d.	14	13	4 13 0	71/3	53/4½	63/–	47/6
1,000,000	Stk. (£1)	Ditto 5½% Cum. 1st Pref. ...	14/6	5½	5½	7 11 9	17/–	13/10½	18/9	15/9
3,850,000	Stk. (£1)	Murex	40/– —1/–	13	22½J	6 10 0	52/–	39/6	45/–	35/3
585,000	5/–	Ratcliffs (Great Bridge) Ord. ...	16/– —3d.	10	10R	3 2 6	16/6	15/9	17/–	14/9
1,064,880	10/–	Sanderson Kayser	33/9 —3d.	17½	35‡	5 3 9	41/3	29/–	40/3	27/7½
3,400,500	Stk. (5/–)	Serck	14/9 —6d.	12½	17½GD	4 4 9	19/3	14/9	25/6	15/3
212,384	5/–	Stedall & Co.	7/9	15	15	9 13 6	10/3	7/6	10/3	6/3
8,035,372	Stk. (£1)	Stone-Platt Industries	50/9 —1/–	16	15	6 6 0	67/–	50/–	64/4½	52/3
2,928,963	Stk. (£1)	Ditto 5½% Cum. Pref.	14/–	5½	5½	7 17 3	18/–	13/6	18/7½	15/3
35,344,881	Stk. (£1)	Tube Investments Ord.	60/– —3/–	14	20	4 13 3	85/6	59/9	140/3	63/10½
41,000,000	Stk. (£1)	Vickers	28/–xd —2/–	10	10	7 2 9	38/3	28/–	39/7½	27/1½
750,000	Stk. (£1)	Ditto Pref. 5%	13/–	5	5	7 13 9	15/–	12/4½	17/6	13/3
6,863,807	Stk. (£1)	Ditto Pref. 5% tax free	18/– —6d.	•5	•5	8 8 0A	21/1½	18/–	24/6	20/1½
4,594,418	1	Ward (Thos. W.) Ord.	69/9 +9d.	13⅜	25	3 18 6	84/6	64/6	94/–	63/–
7,109,424	Stk. (£1)	Westinghouse Brake	29/6 —9d.	11	10	7 9 3	46/3	29/6	60/6	37/6
323,773	2/–	Wolverhampton Die-Casting ...	8/8	35	30	8 9 9	13/4½	8/–	13/10½	8/1½
591,000	5/–	Wolverhampton Metal	22/9 —6d.	32½	32½	7 2 9	30/–	21/3	39/9	23/9
156,930	2/6	Wright, Bindley & Gell	4/3	15	20‡	8 16 6	4/9	3/7½	4/6	2/10½
124,140	1	Ditto Cum. Pref. 6%	12/9	6	6	9 8 3	13/7½	12/9	15/–	13/6
150,000	1/–	Zinc Alloy Rust Proof	4/4½	40	30	9 2 9	5/6	4/3	5/4½	4/–

•Dividend paid free of Income Tax. †Incorporating Zinc Corpn. & Imperial Smelting. ••Shares of no Par Value. ‡and 100% capitalized issue. •The figures given relate to the issue quoted in the third column. A Calculated on £7 8 9 gross. D and 50% capitalized issue. C paid out of Capital Profits. E and 50% capitalized issue in 7% 2nd Pref. Shares. R and 33⅓% capitalized issue in 8% Maximum Ordinary 5/– Stock Units. ϕ and 6½% from Capital Profits. B and 50% capitalized issue. G and 50% capitalized issue. F and special 5% tax free dividend and 50% capitalized issue. ¶and 3 for 7 capitalized issue. L and 33⅓% capitalized issue. M and 10% capitalized issue. J and 75% capitalized issue. Q also 1/– special tax free dividend and 50% capitalized issue. T Per £1 unit. K Forecast dividend. S and 50% capitalized issue. V incorporating Clifford Covering.

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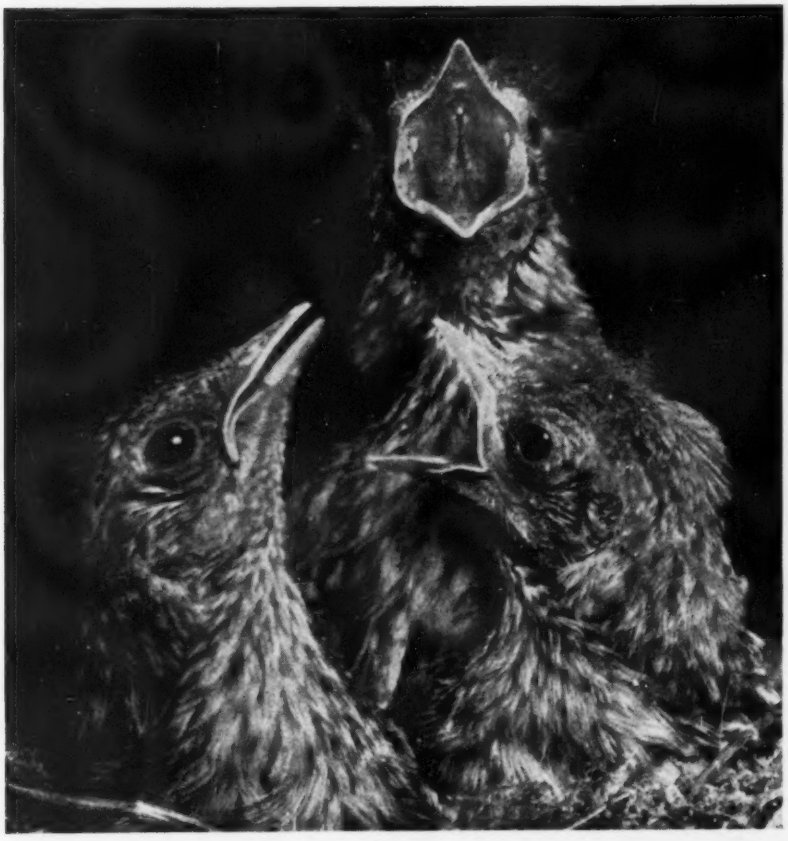

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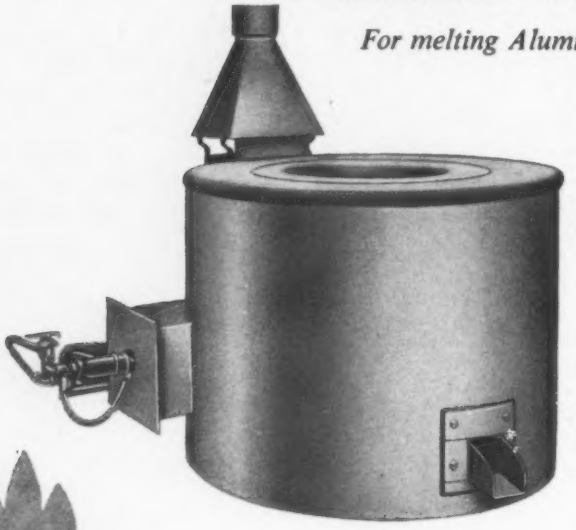

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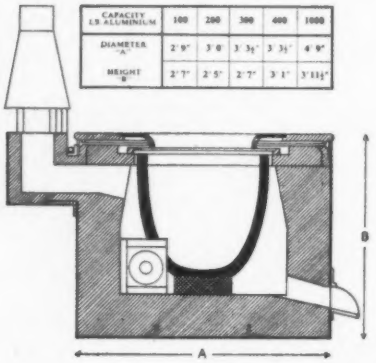
HEIGHT B	2'7"	2'5"	2'7"	3'1"	3'11½"



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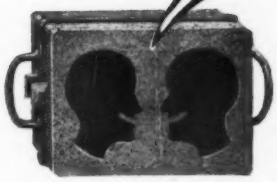

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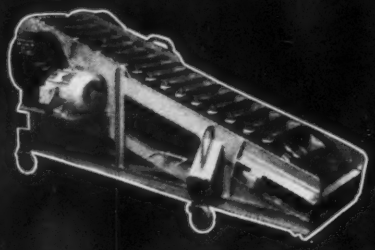

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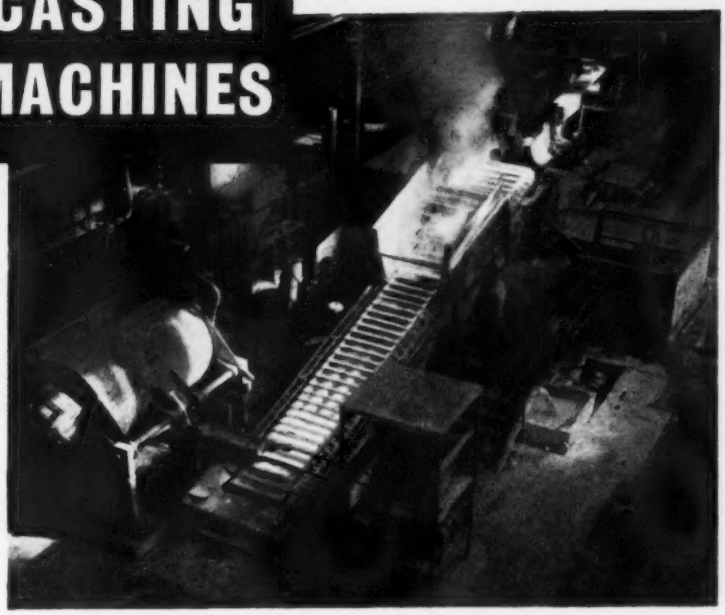

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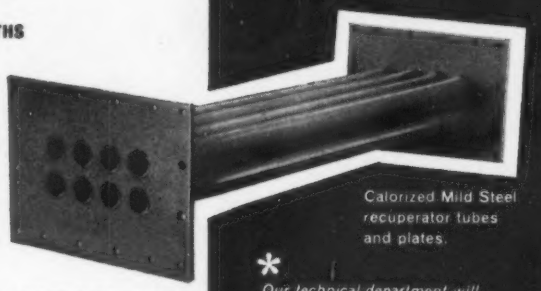

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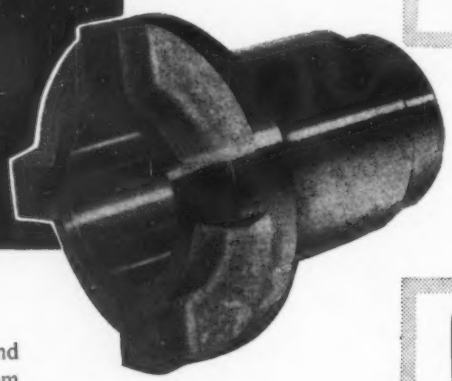

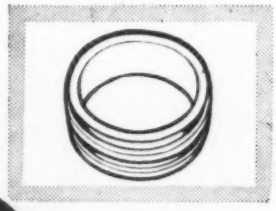

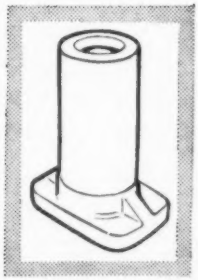

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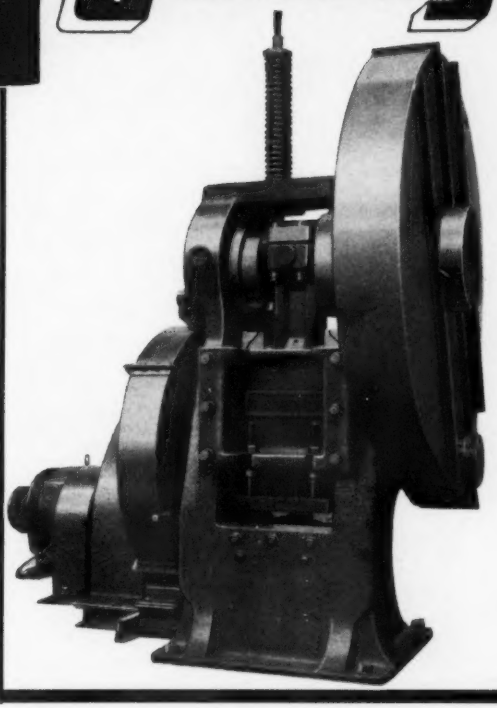

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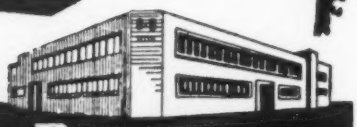

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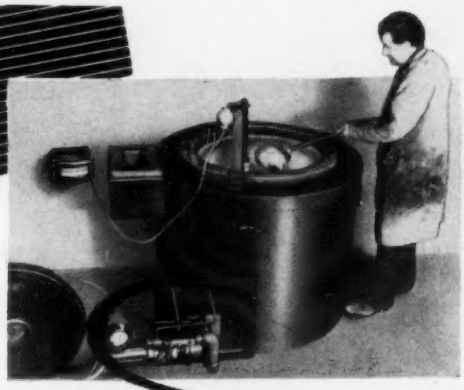

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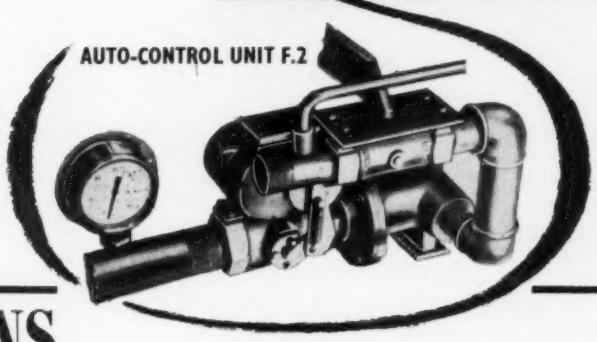

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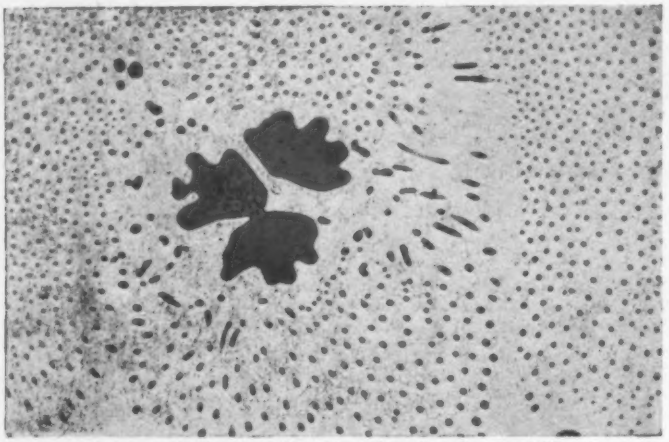

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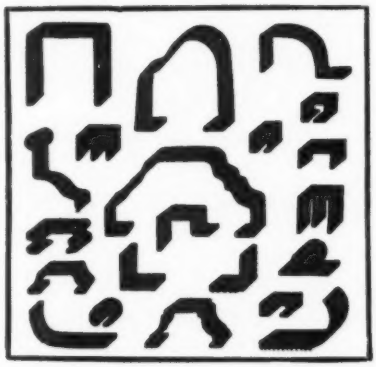

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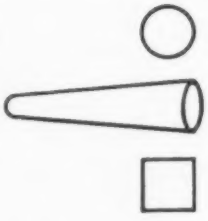

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